Geological Survey of Canada
Commission géologique du Canada

PAPER 86-15

GEOLOGY OF THE DOUBLE MER WHITE HILLS AND SURROUNDING REGION, GRENVILLE PROVINCE, EASTERN LABRADOR

Charles F. Gower

1986

Canada

86-04934/

DEPARTMENT OF MINES AND ENERGY
GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

CONTRIBUTION TO CANADA-NEWFOUNDLAND CO-OPERATIVE MINERAL PROGRAM 1982–84

The author is employed by the Newfoundland Department of Mines and Energy. Field operations, field support staff, and publication production were funded by Canada. Office, ancillary services, and chemical analyses were provided by Newfoundland.

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GEOLOGICAL SURVEY OF CANADA
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or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Canada K1A 0S9

and from

Geological Survey of Canada offices:

601 Booth Street
Ottawa, Canada K1A 0E8

3303-33rd Street N.W.,
Calgary, Alberta T2L 2A7

A deposit copy of this publication is also available
for reference in public libraries across Canada

Cat. No. M44-86/15E Canada: $7.00
ISBN 0-660-12114-X Other countries: $8.40

Price subject to change without notice

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Original manuscript received: 1985-03-28
Final version approved for publication: 1985-12-13

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GEOLOGY OF THE DOUBLE MER WHITE HILLS AND SURROUNDING REGION, GRENVILLE PROVINCE, EASTERN LABRADOR

Abstract

The Double Mer White Hills map area is located in the Grenville Province, eastern Labrador. Major rock groups recognized are orthogneiss, metasedimentary gneiss, granitoid plutons, granulite facies rocks, gabbroid intrusions and the post-Grenvillian Double Mer Formation.

The dioritic to granitic orthogneiss and the dominantly pelitic to psammitic metasedimentary gneiss, are interpreted as representatives of a sedimentary-plutonic terrane that was subjected to severe tectonothermal activity at ca. 1.65 Ga. The granitoid plutons are either the less deformed parts of the orthogneiss or slightly younger granitoid plutons. Corona-textured gabbroid intrusions generally can be assigned to the ca. 1.4 Ga Michael gabbro, but probably include remnants of the ca. 1.65 Ga Adlavik Intrusive Suite. The Double Mer Formation consists of terrigenous redbeds confined to a post-Grenvillian half-graben.

The map area includes parts of three major crustal segments, the Trans-Labrador batholith and the Groswater Bay and Lake Melville terranes. These are lithologically and structurally distinct regions with a zonal metamorphic pattern from greenschist facies in the northwest to granulite facies in the southeast. The deepest level rocks exposed were metamorphosed to about 9-10 kb and 800°C. Metamorphism terminated with Grenvillian orogenesis, involving uplift of deeper level metamorphic rocks from the south, and slicing of the region into thrustbound lithotectonic terranes.

Prospects for mineralization of economic interest, which appear low, are confined to minor copper staining associated with pyritic metasedimentary gneiss.

Résumé

La région levée désignée sous le nom de Double Mer White Hills est située dans la province de Grenville à l'est du Labrador. Les formations rocheuses principales sont les orthogneiss, les gneiss métasédimentaires, les plutons granitoïdes, les roches à faciès granulitique, les intrusions gabbroïdes et la formation post-grenvillienne Double Mer.

Les orthogneiss dioritiques et granitiques et les gneiss métasédimentaires pélitique à psammifiques prédominants sont interprétés comme représentatifs de terrains sédimento-plutoniques qui ont été soumis à une activité tectonothermale qui eut lieu autour de 1,65 Ga. Les plutons granitoïdes sont qu'ils soient la partie la moins déformée des orthogneiss ou qu'ils soient légèrement plus jeunes. Les intrusions gabbroïdes à texture en couronne sont généralement reconnues comme des gabbros Michael datant d'environ 1,4 Ga, mais ces intrusions renferment probablement des restes de la série intrusive Adlavik datant d'environ 1,65 Ga. La formation Double Mer consiste en des "redbeds" terrigènes confinés dans un demi-graben post-grenvillien.

La région levée comprend des parties de trois segments crustaux importants qui sont le batholithe Trans-Labrador et les terrains Groswater Bay et Lake Melville. Ces entités tectoniques déterminent des régions lithologiquement et structurellement distinctes accompagnées d'une configuration métamorphique zonale provenant au nord-ouest d'un faciès de schistes verts et passant à un faciès granulitique au sud-est. Les affleurements rocheux qui accusent la plus grande profondeur ont été métamorphisés à des pressions et des températures respectives de l'ordre de 9-10 kb et 800°C. Le métamorphisme s'est achevé avec l'orogène grenvillienne, ce phénomène a provoqué un soulèvement de couches rocheuses métamorphiques profondes au sud de la région et a fracturé la région en des terrains lithotectoniques à limites faillées chevauchantes.

Cette région a un potential de minéralization d'intérêt économique limité; cette minéralisation est constituée de venues cuprifères mineures associées à des gneiss métasédimentaires pyritiques.

INTRODUCTION

Location and access

The area treated in this report is in central-eastern Labrador and is bounded by 54°00′ and 54°30′N and 59°00′ and 60°30′W (Fig. 1). It includes six NTS 1:50 000 sheet areas, namely 13J/3, 13J/4, 13J/5, 13J/6, 13K/1 and 13K/8, collectively embracing an area of approximately 5500 km^2. The southwest and northeast corners of the area are respectively about 75 km north of and 160 km northeast of Goose Bay.

The area is readily accessible from Goose Bay by air. The most satisfactory means of access is by helicopter but fixed-wing aircraft may be used on those lakes where boulders do not pose a hazard. The southeast part of the area may also be reached by boat using Double Mer, and by canoe along Main River which flows into the head of Double Mer. This river is, however, very shallow in places and has numerous rapids without established portages. Rivers elsewhere are too shallow and/or swift to permit effective canoe use. Overland access is hampered by extensive swampy lowlands or spruce forest on hills. Only in the lichen or moss covered areas above treeline, in the southeast part of the region, is foot access comparatively easy.

There are no roads or trails in the area at present; however the route of a proposed road from Northwest River to Michelin crosses the western part of the area. There are no permanent settlements in the area, but a fishing lodge at the head of Double Mer is occupied during the summer, and the region is visited occasionally by trappers during the winter.

Several place names are shown on the accompanying 1:100 000 map that do not appear on existing topographic maps. These are recently approved official new names (Newfoundland Gazette, 1980a,b).

Previous work

The 1:506 880 scale map of eastern and central Labrador by Christie et al. (1953) gives very little geological information about the present area but it does show the Double Mer Formation (Kindle, 1924), faulted against granitoid gneisses to the north. Knowledge of the gneisses probably is based on a report by Halet (1946) who noted, in particular, south-dipping gneisses in the high area north of Double Mer (referred to as Mt. Calvin, but now known officially as Double Mer White Hills).

Reconnaissance geological mapping was first conducted throughout the area by British Newfoundland Corporation Ltd. (BRINCO) in 1954 as part of a much larger project (Beavan, 1954; 1955, especially Appendix I on area "D" by M.J. Piloski). Piloski described the dominant bedrock as hornblende-garnet gneiss, associated with numerous mafic intrusions. The gneissic protolith was inferred to be metasedimentary and correlated with Aillik Group supracrustal rocks farther north. The mafic intrusions were mapped as olivine and pyroxene gabbro and diorite, and corona textures around mafic phases observed. Massive hornblende-biotite granite, syenite, monzonite and rare diorite (subsequently grouped with the Otter Lake – Walker Lake granite; Ryan and Harris, 1978; Smyth, 1977; Bailey, 1978; Ryan, 1982), were mapped north of the gneiss. The boundary between granite and gneiss and the distribution of some mafic intrusions are shown on a map by Morrison (1957).

Airborne electromagnetic, magnetic and radiometric traverses were conducted for British Newfoundland Exploration Co. Ltd. (BRINEX) north and southwest of Double Mer and some radiometric anomalies reported (Wagg, 1968). A more extensive airborne geophysical survey was carried out on 13K/8 as part of a Canico-Brinex joint venture (Perry, 1979).

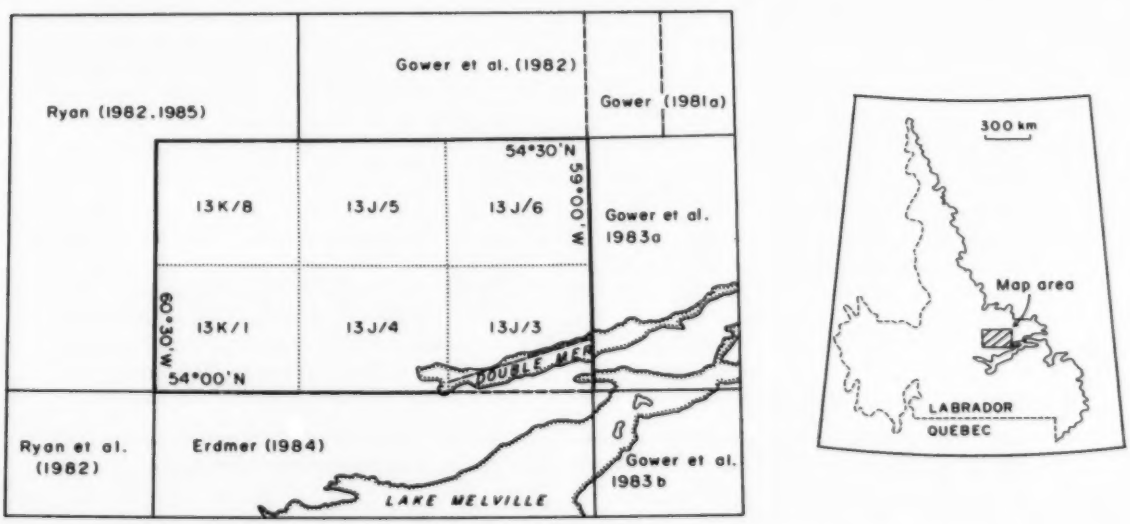

Figure 1. NTS map sheets for Double Mer White Hills map area (heavy outline), and most recent work done in surrounding region. Dashed boundaries indicate areas of overlap between maps.

Systematic reconnaissance geological mapping at 1:250 000 scale was carried out by the Geological Survey of Canada; NTS sheet 13K (east half) was mapped by Williams (1967, 1970) and 13J by Stevenson (1969, 1970). Williams confirmed Morrison's separation of granitoid rocks in the north from gneisses farther south, but positioned the boundary farther north than did Morrison. Stevenson showed most of the eastern two-thirds of the present map area to be underlain by gneiss. He distinguished granulite facies rocks in the Double Mer White Hills area and recognized that gneiss south of Double Mer was different from that north of Double Mer White Hills. The mapping of Williams and Stevenson formed the basis for Greene's (1972) compilation of the geology of Labrador in this area. Subsequent work based on Stevenson's mapping included a K-Ar (biotite) age determination (1160 Ma, recalculated using IUGS recommended constants; Steiger and Jäger, 1977) on gneiss 26 km north-northwest of Double Mer White Hills (Wanless et al., 1972; Sample No. GSC 70-135), and paleomagnetic studies on selected gabbros (Fahrig and Larochelle, 1972).

Airborne magnetic surveys of the area were carried out during 1969 and 1970. Aeromagnetic maps based on these surveys have been published at 1:63 360 scale (Geological Survey of Canada, 1970 a,b; 1971 a,b,c,d) and at 1:250 000 scale (Geological Survey of Canada, 1976 a,b).

Lake sediment sampling undertaken during the Uranium Reconnaissance Program (URP) has now been completed for the map area (Geological Survey of Canada/Newfoundland Department of Mines and Energy, 1977, 1984). Follow-up work resulted in the discovery of uranium mineralization between Double Mer and Lake Melville, south of the present area (McConnell, 1979; Kerswill and McConnell, 1982). The mineralization has been investigated further by Northgate Exploration Ltd., which also conducted a limited drilling program. Bailey (1979a, 1980) made an initial geological assessment of the mineralized area, and later the district was included as part of a reconnaissance mapping project by Erdmer (1983, 1984). Data from Erdmer's map for 13J/3 south of Double Mer are included in the present map. Adjacent areas in which 1:100 000 scale geological mapping has been done recently are outlined in Figure 1.

Present investigation

The present investigation had two main objectives. The first was to complete reconnaissance geological mapping at 1:100 000 scale in eastern Labrador north of 53°30′N and thus permit a regional synthesis of the northern flank of the eastern Grenville Province (Gower and Owen, 1984a; Gower and Ryan, in press; Wardle et al., in press). The second objective takes into account that the area is located between mineralized (U-Mo) felsic volcanics of the upper Aillik Group (ca. 1750-1650 Ma) in the Michelin area to the north and uraniferous metasedimentary gneiss in the Double Mer – Lake Melville area to the south. In addition, the URP sampling showed an arcuate zone (50 by 7 km) of anomalous U-Mo and locally Zn and Cu values (*see* Economic mineral potential) within the map area. Thus the region is potentially important in understanding regional metallogenesis in eastern Labrador.

Helicopter-supported mapping was conducted from mid-June to mid-August 1983. Selected ground traverses were done in the better exposed southeast part of the area, but elsewhere mapping was mostly restricted to visiting specific outcrops that were either known previously, or indicated from black-and white or infrared aerial photographs, or spotted during helicopter traversing.

Physiography

The map area can be divided physiographically into five subparallel, east-northeast-trending sectors, reflecting contrasts in bedrock as follows (from northwest to southeast): (i) the Otter Lake – Walker Lake granite, (ii) Groswater Bay terrane, (iii) Lake Melville terrane north of Double Mer, (iv) Double Mer Formation, (v) Lake Melville terrane south of Double Mer.

The area underlain by Otter Lake – Walker Lake granite is characterized by low, rounded hills with sporadic granitoid outcrops, and steeper, long, sinuous ridges of gabbro. The intervening lowlands are occupied by large, shallow lakes interconnected by well defined streams.

This topography grades southward into a gently undulating terrain where most bedrock is concealed under glacial deposits. Elevation above sea level is generally between 300 and 350 m with scattered knolls rising 15 to 50 m above the general land surface. The knolls are mostly underlain by gabbro, and, although this comprises much of the rock exposure, the dominant bedrock, seen in stream beds and marginal to gabbro, is quartzofeldspathic gneiss.

The drainage shows a strong east-northeast preferred orientation reflecting a close relationship between glacial drainage pattern (as indicated by eskers) and present day drainage. Drainage basins are shown in Figure 2. Many eskers can be traced for more than 20 km, and one for more than 50 km. Eskers trend in two directions, southeast and east-northeast; eskers trending southeast are truncated by those trending east-northeast (Fig. 3).

A well defined terminal moraine, trending west-northwest, is evident from aerial photographs in the western part of the map area and has been termed the Sebaskachu moraine by Fulton and Hodgson (1979). Elsewhere shallow, boulder-filled lakes, string-bogs, erratic streams and mounds of glacial debris characterize the landscape.

The Lake Melville terrane north of Double Mer forms an upland, generally exceeding 350 m in elevation and reaching 700 m in the Double Mer White Hills. It is underlain by granulite facies gneisses that dip southward and are in thrust contact with rocks of the Groswater Bay terrane, a feature reflected topographically by an abrupt north face, in contrast to a gently inclined south slope.

A marked break in topography between the Double Mer White Hills upland area and the coastal plain north of Double Mer corresponds with a fault that bounds the Double Mer half-graben. The coastal plain is underlain by Double Mer Formation and forms a low-lying area up to 12 km wide and generally less than 100 m high. The shoreline of Double Mer in this region is marked by a wide boulder fringe composed of

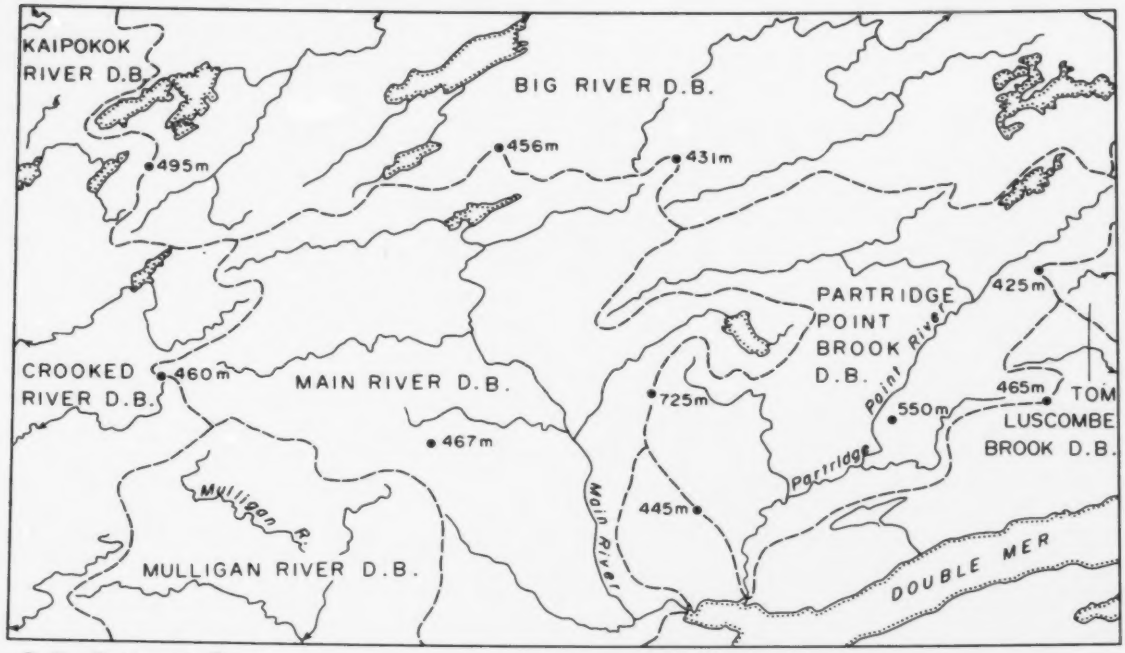

Figure 2. Drainage basins in Double Mer White Hills area. Minor drainage basins marginal to Double Mer have not been delineated or named.

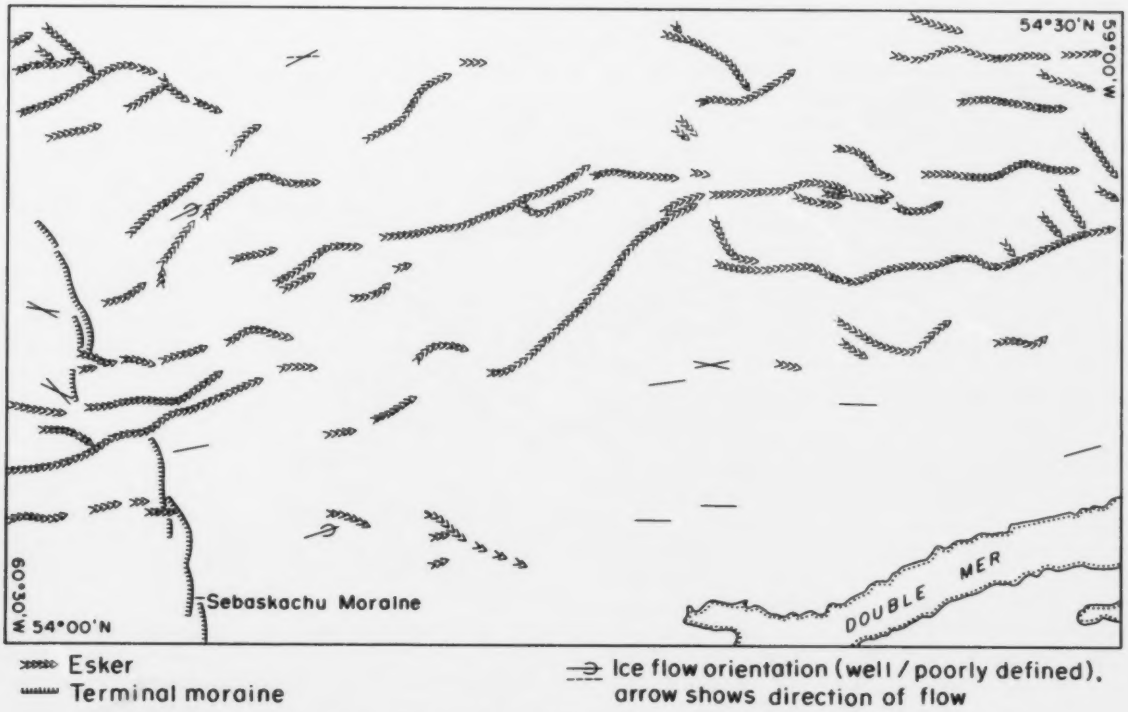

Figure 3. Principal glacial features in the Double Mer White Hills area. Ice flow directions from Klassen (1984). Sebaskachu moraine was named by Fulton and Hodgson (1979).

material partly derived by erosion of Double Mer conglomerate.

The rugged area underlain by rocks of the Lake Melville terrane south of Double Mer consists of steep-sided, east-northeast-trending ridges and hills. This topography reflects alternating layers of orthogneiss and paragneiss, associated with strike-slip faults.

Acknowledgments

The project was carried out under the Canada – Newfoundland co-operative mineral program 1982-84 and was funded by Department of Mines and Energy, Government of Newfoundland and Labrador and by Department of Energy, Mines and Resources, Geological Survey of Canada. Field work was aided by able and cheerful assistants, Peter King and Tony Power. Expediting service from Goose Bay was carried out by Ken O'Quinn and Wayne Tuttle of the Newfoundland Department of Mines and Energy. Versatile Air Services provided excellent helicopter support through their pilots Earl McFarland and Bob Bartlett and engineer Ron Davis. Fixed wing aircraft support was reliably provided by Newfoundland Air Transport Ltd. The manuscript has benefited from discussions with Bruce Ryan and Philippe Erdmer who mapped adjacent areas, and from constructive and critical reviews by Tony Davidson, Lawson Dickson, Dan Kontak and Marc St-Onge. The map and figures were drafted by Dave Leonard, Tony Paltanavage and Kelly Steinhauer, supervised by Ken Byrne of the Newfoundland Department of Mines and Energy. The manuscript was typed by Denise Gamberg.

REGIONAL SETTING

Within the Grenville Province of eastern Labrador four major lithotectonic regions have been recognized (Gower, 1984; Gower and Owen, 1984a,b). From north to south these are: (i) Trans-Labrador batholith, (ii) Groswater Bay terrane, (iii) Lake Melville terrane, and (iv) Mealy Mountains Intrusive Suite. In addition, the region includes areas underlain by terrestrial redbed sediments of the Double Mer Formation, associated with post-Grenvillian graben and half-graben structures (Fig. 4).

Granitoid rocks form a belt along the northern flank of the Grenville Province across much of Labrador. Recognized collectively by geologists of the Newfoundland Department of Mines (e.g. Gower, 1981b), it was subsequently named the Trans-Labrador batholith by Wardle and staff (1982). Rock types include granodiorite, granite, quartz syenite and quartz monzonite. Individual plutons have generally yielded 1650-1600 Ma ages by both U-Pb (zircon) and Rb-Sr (whole-rock) methods. Summaries of geochronological data are given by Gower and Ryan (in press) and Thomas et al. (in press). The northern flank of the batholith intrudes Archean – Lower Proterozoic gneissic rocks and Lower Proterozoic supracrustal rocks of the lower Aillik Group. The southern

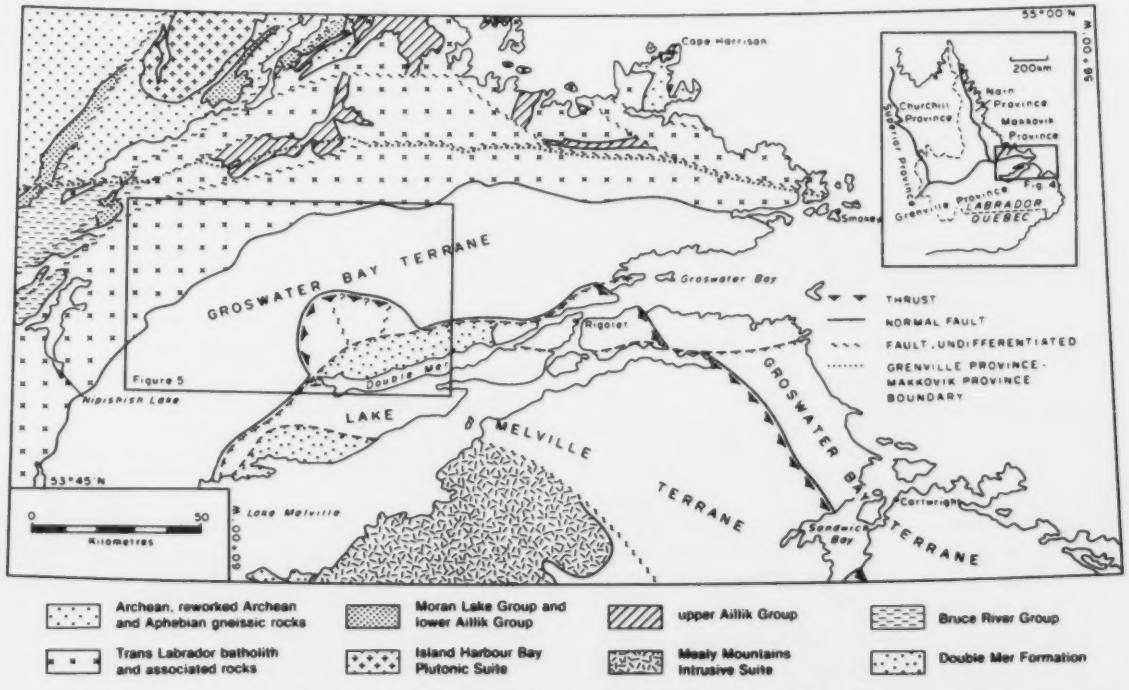

Figure 4. Lithotectonic terranes in eastern Labrador; map area described in this report is outlined.

flank is poorly exposed and thus ill-defined, and could be either an intrusive or structural boundary, or a metamorphic transition. Felsic volcanic rocks of the upper Aillik Group (ca. 1750-1650 Ma) are closely associated spatially and probably genetically with (and intruded by) the Trans-Labrador batholith (Bailey, 1979b). The batholith is in part unconformably overlain by terrestrial sedimentary and volcanic rocks of the Bruce River Group (ca. 1530 Ma) in central Labrador (Smyth et al., 1975) although the very latest plutonism (e.g. Otter Lake granite, ca. 1496 Ma) postdates supracrustal rocks (Ryan, 1981).

The Trans-Labrador batholith straddles the boundary between the Makkovik and Grenville provinces in eastern Labrador. The boundary shown in Figure 4 is modified from Gower et al. (1980) to follow a more southerly course in the region north of the present map area. The revised position, based on re-examination of some outcrops during the 1983 field season, is considered to be more consistent with structural contrasts on either side of the adopted line farther east and west. Also the revised line appears to coincide with both the northernmost occurrence of Michael gabbro and northern limit of Grenvillian K-Ar radiometric ages. Mafic intrusions farther north, previously not distinguished from Michael gabbro (Bailey, 1981; Gower et al., 1982), are texturally and compositionally distinct, being typical of the Adlavik Intrusive Suite; that is to say, they are coarser grained, contain common amphibole and show compositional layering in some outcrops.

The Groswater Bay terrane is an arcuate belt about 50 km wide and at least 350 km long. Rock types include tonalite/granodiorite orthogneiss which is dominant, and subordinate pelitic/psammitic metasedimentary gneiss, K-feldspar megacrystic and seriate-textured granodiorite, diorite, pyroxene-bearing granitoid intrusions and mafic rocks of various ages. The orthogneiss has yielded ages ranging from 1680 Ma (U-Pb zircon, Krogh, 1983) to 1610 Ma (Rb-Sr whole-rock, Brooks, 1983), significantly older than Grenvillian K-Ar ages of 1160 Ma (biotite) to 927 Ma (muscovite), (Wanless et al., 1972; Grasty et al., 1969) in the same region. The dioritic, granodioritic and pyroxene-bearing intrusions contrast with the enveloping gneiss in forming more homogeneous, coherent bodies, but relationships between the gneiss and the granitoid plutons are still uncertain.

Two major suites of mafic intrusions have been identified (Gower and Owen, 1984a) within the Groswater Bay terrane at ca. 1.6 Ga (*cf.* Adlavik Intrusive Suite) and ca. 1.4 Ga (*cf.* Michael gabbros). In addition, there are several sets of mafic dykes. Structural trends of gneiss and foliated granitoid plutons are north to northeast. The observed grade of metamorphism is the product of more than one metamorphic event. The highest grade rocks are preserved adjacent to the Lake Melville terrane. Epidote is characteristic of orthogneiss and kyanite is common in metasedimentary gneiss, especially in the southern half of the Groswater Bay terrane.

The Lake Melville terrane is about 60 km wide (where not disrupted by post-Grenvillian faulting) and is separated from the Groswater Bay terrane by a series of thrusts (Rigolet thrust zone). Rock types include granodioritic orthogneiss, pelitic and semipelitic gneiss, quartz diorite to monzonite, K-feldspar megacrystic granodiorite, hornblende- and/or clinopyroxene-bearing granodiorite to syenite, and various mafic intrusive rocks. This range of lithologies is similar to that of the Groswater Bay terrane, but proportions differ. In particular, metasedimentary gneiss is more abundant and includes minor calc-silicate rocks and quartzite. K-feldspar megacrystic granodiorite, uncommon in the Groswater Bay terrane, is a major rock type in the Lake Melville terrane, especially near its northern border. In contrast, mafic rocks are less abundant in the Lake Melville terrane, except in a broad zone near its northern flank, where several major layered gabbro-anorthosite-monzonite intrusions occur.

Structural trends in the Lake Melville terrane are more variable than in the Groswater Bay terrane and, at least along the northern border, the metamorphic grade is higher. This region, termed the Mount Gnat granulite belt (Gower and Owen, 1984a), is characterized by two-pyroxene garnet mafic granulite associated with sillimanite + hypersthene + K-feldspar-bearing metasedimentary gneiss. Sillimanite is the characteristic aluminosilicate phase throughout the Lake Melville terrane and locally is accompanied by cordierite. Epidote is absent in orthogneiss, except as a retrograde mineral.

The Mealy Mountains Intrusive Suite comprises leucotroctolite, leucogabbro, anorthosite and related rocks, intruded by pyroxene quartz monzonite (Emslie, 1976). Emslie et al. (1983) have reported ages of 1678 ± 77 Ma (Rb-Sr, whole-rock) and 1640 ± 3 Ma (U-Pb, zircon) for monzonite-granite that forms part of the suite. These rocks were subsequently intruded by olivine diabase dykes (Mealy dykes), dated at 1380 ± 54 Ma (Rb-Sr, whole-rock, Emslie et al., 1983). The west, northwest and northeast sides of the Mealy Mountains Intrusive Suite are bounded by faults, but a southeast lobe appears to be intrusive. Gower and Owen (1984b) have suggested that the Mealy Mountains Intrusive Suite probably is part of a separate terrane for which they proposed the name Mealy Mountains terrane.

The Double Mer White Hills map area is located near the northern margin of the Grenville Province, within the Grenville Front Zone, as depicted by Gower et al. (1980). Except for the Mealy Mountains Intrusive Suite, it includes portions of each lithotectonic terrane outlined above.

A geological sketch map of the study area is shown in Figure 5 (see also Map 10-1986, in pocket).

DIORITIC, GRANODIORITIC AND GRANITIC ORTHOGNEISS, MINOR AMPHIBOLITE (UNIT 1)

The orthogneisses of unit 1 have been subdivided, in order of decreasing colour index as follows; amphibolite (unit 1a), dioritic gneiss (unit 1d), hornblende granodiorite gneiss (unit 1h), biotite granodiorite gneiss (unit 1b), K-feldspar augen granodiorite gneiss (unit 1p), fine grained biotite granodiorite to granite gneiss (unit 1f), muscovite-biotite granite gneiss (unit 1g).

These gneissic rock types occur as interleaved units with gradational boundaries and, as indicated on the 1:100 000

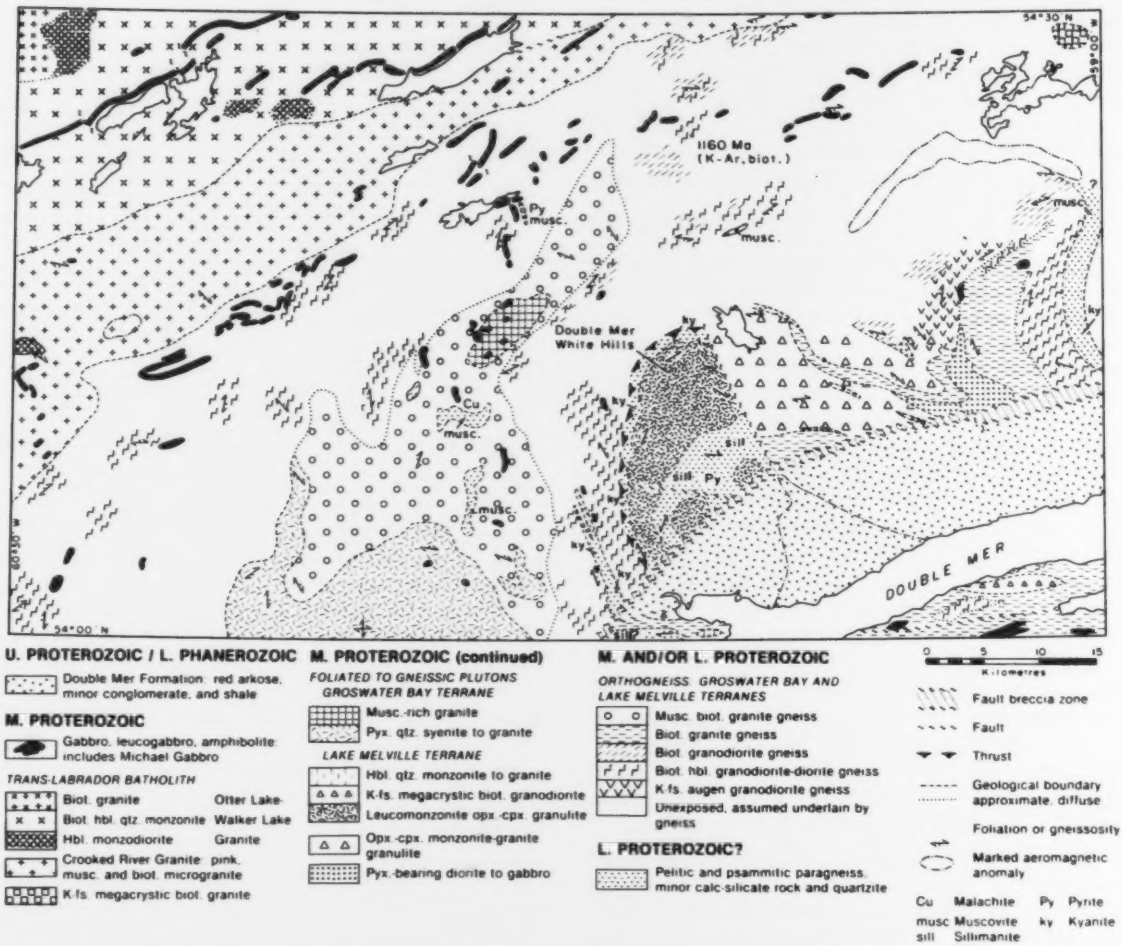

Figure 5. Regional bedrock geology of map area. The area south of Double Mer is compiled from Erdmer (1984).

geological map (in pocket), several types may be present in a single outcrop. In places, composite symbols have been used. Depicting particular outcrops in this way is intended to convey to the map user that there is uncertainty as to how they should be designated. The uncertainty is due to either variable lithological characteristics within a single outcrop, such as gneiss grading into foliated granitoid rock (e.g. 1h/4h), or inadequate information to allow a more definative designation (e.g. 1a/4a/7a). The latter reason may be due to project or terrain constraints (brevity of helicopter stop, poor outcrop), or simply that they are isolated outcrops showing some features common to several units, but none deemed essential to identify the rock type more specifically.

Amphibolite (unit 1a)

Unit 1a comprises dark green to black weathering, coarse grained, recrystallized mafic to ultramafic rocks. Relict layering is present rarely and the rocks are intruded by granitoid dykes and quartz veins. An example from upper Main River consists of clinopyroxene, pale green amphibole, recrystallized garnet, quartz, plagioclase, orange-brown biotite and minor K-feldspar, sphene, apatite and opaque minerals (sulphide cores with ilmenomagnetite rims). North of Double Mer Barrens a sample comprises hornblende, clinopyroxene, calcic plagioclase (An_{72}), abundant scapolite and accessory minerals. The scapolite is unusual in that it is cored by opaque minerals. Amphibolite mapped by Erdmer (1984) south of Double Mer (his unit Ham) has also been designated as unit 1a here.

Dioritic gneiss (unit 1d)

Dioritic gneiss underlies an elongate north-northeast-trending area west of upper Main River. Much of the unit is relatively homogeneous, rather than a well banded gneiss, and for this reason the composite symbol 1d/4d has been used, except for two outcrops which show good gneissosity.

The rock is mostly black and white weathering, medium grained, with pink or white concordant leucosome layers. It consists of plagioclase, hornblende and biotite, with accessory quartz, garnet, scapolite, clinopyroxene, K-feldspar, apatite, sphene, epidote and allanite. The major mineral phases occur in clusters which are interpreted as the recrystallized products of much larger grains, in an originally coarse grained rock.

The locality sampled for radiometric dating by Wanless et al. (1972) has been designated here as unit 1d/4d, although Stevenson (*in* Wanless et al., 1972) described the dated sample as a biotite-rich paragneiss. It gave an age of 1160 ± 40 Ma (K-Ar, biotite; recalculated from the 1150 Ma age originally quoted using IUGS recommended constants of Steiger and Jäger, 1977). The only outcrop located during the present mapping in the vicinity is a foliated to gneissic amphibole-bearing rock with pink to white leucosome bands, which, in slabs stained for K-feldspar, resembles dioritic gneiss farther west. A thin section of the rock is more accurately described as hornblende granodiorite and contains plagioclase, quartz, microcline, hornblende, green biotite, epidote with allanite cores, sphene, apatite and secondary calcite and chlorite. Wanless et al. (1972) also noted that their dated mineral concentrate contained hornblende. The rock is interpreted as derived from a plutonic rather than sedimentary protolith.

Dioritic gneiss also occurs at two localities in the northeast part of the region. These rocks grade into, or are interleaved with, hornblende granodiorite gneiss and include leucosome layers with large hornblende crystals. The latter texture is interpreted to have formed by incongruent melting of the host rock to give hornblende + melt.

In the eastern part of the map area, a single outcrop of melanocratic diorite with abundant garnet has also been grouped with unit 1d. This is a somewhat equivocal designation because, although a stained slab shows the rock to contain significant amounts of K-feldspar, the field and textural characteristics have similarities to nearby (K-feldspar deficient) gabbro. The outcrop is on strike with metagabbro farther south, and thus may be a potassium metasomatized extension.

Hornblende-biotite granodiorite to quartz diorite gneiss (unit 1h)

Rocks classified as hornblende-biotite granodiorite to quartz diorite gneiss are grouped into four areas within the Groswater Bay terrane. These are, (i) extreme southwestern area, (ii) headwaters of Mulligan River, (iii) Main River and northeast of Main River, and (iv) eastern part of the map area.

The gneisses in the southwestern area are black and white weathering, medium grained hornblende-biotite granodioritic rocks. Although the gneiss is commonly well banded, homogeneous zones do exist in some outcrops. Leucosome is present as quartzofeldspathic layers, pods and patches which may bear hornblende. Banding is defined by intercalated paleosome, leucosome and elongate mafic enclaves. Plagioclase, K-feldspar, quartz, biotite and epidote are major mineral phases with accessory hornblende, garnet, allanite, apatite, sphene, zircon and opaque minerals. Hornblende is a relict phase, having been extensively replaced by biotite + epidote. The rocks in this area are characterized by multiple allanite-epidote growth stages.

Farther east, in the area of the headwaters of Mulligan River, outcrops are shown on the map as 1h/4h. They are black and white weathering, medium- to coarse-grained rocks of granodioritic, tonalitic or quartz dioritic composition. Throughout the unit leucosome is poorly developed and in some outcrops is nonexistent. Where present, leucosome is manifest as wispy, subparallel, irregular or tightly folded layers containing hornblende and having biotite selvages. The main textural distinctions between this group and unit 1h farther west are coarser grain size and less well developed gneissosity. The rocks are very similar mineralogically, including biotite + epidote replacement of hornblende and multiple allanite-epidote growth stages. These rocks differ from the adjacent quartz diorite gneiss to the east in having more quartz and K-feldspar and less hornblende.

The biotite-hornblende granodiorite, tonalite and quartz diorite gneisses (mostly mapped as unit 1h,d) adjacent to Main River (especially the eastern side) are among the best exposed in the whole region. The rocks are grey, creamy or locally pink weathering and are typically medium grained. The fabric varies from foliated to well banded with gneissosity defined by coarser grained quartzofeldspathic layers and amphibole-rich schlieren. Major minerals are plagioclase, quartz, hornblende, biotite and commonly also scapolite and garnet; minor minerals include epidote, allanite, apatite, sphene, ilmenomagnetite and secondary chlorite. Except for one very poor example, the multiple allanite – epidote growth stages, seen in granodiorite – quartz diorite in the upper Mulligan River area, are not present. Toward the Double Mer fault the rocks are brecciated and partly altered, with extensive epidote, hematite and chlorite developed.

Isolated outcrops northwest and north-northeast of Double Mer White Hills are composed of similar medium grained, biotite-hornblende granodiorite to quartz diorite gneiss, and it is probable that this gneissic type is continuous around the north and west flanks of Double Mer White Hills.

Grey weathering granodioritic, tonalitic and quartz dioritic gneiss in the eastern part of the region has more compositional and textural variability than unit 1h elsewhere in the region. Interdigitating granodioritic to dioritic rock types within a single outcrop are typical, and grain size, although dominantly medium, also includes fine to coarse layers. A well developed layering is defined by biotite schlieren, amphibole-rich enclaves and leucosome lenses. An example of the unit consists of plagioclase, quartz, hornblende, biotite, garnet and scapolite with accessory K-feldspar, apatite, ilmenomagnetite, epidote, allanite and secondary chlorite. Garnet is locally seen in outcrop as clusters up to 1 cm across.

Granodiorite gneiss (unit 1b)

Granodioritic gneiss with biotite as the dominant mafic phase occurs adjacent to the Crooked River granite (unit 4f), and north of Double Mer Barrens.

The biotite granodiorite gneiss adjacent to the Crooked River granite is a heterogeneous group of rocks which also includes quartz monzodiorite and pink and grey weathering, medium grained, well banded, complexly folded gneiss with sparse K-feldspar megacrysts locally. Farther east (13J/5) the gneisses are grey to buff weathering and medium grained with biotite schlieren, thin amphibolite skialiths and diffuse to well defined leucosome layers. The more southerly outcrops in this area are leucocratic and muscovite-bearing, possibly indicating intermixing with muscovite-biotite granite gneiss (unit 1g) farther south. The most easterly gneiss in this zone (in 13J/6) is a grey weathering, fine- to medium-grained biotite granodioritic rock with foliated to gneissic fabrics, discontinuous leucosome and, locally, tight to isoclinal folds.

All these rocks contain plagioclase, quartz, microcline and olive-green biotite as major phases with accessory epidote, allanite, sphene, apatite and opaque minerals. Relict blue-green amphibole is locally present and the more granitic compositions also contain garnet and minor muscovite.

Biotite granodiorite gneisses north of Double Mer Barrens are grey to pink weathering, medium grained rocks with a well developed gneissosity, which is isoclinally folded in places. These rocks grade into granitic gneiss. They are composed of plagioclase, quartz, untwinned K-feldspar, and bronzy green biotite, with accessory apatite, allanite and opaque minerals. Garnet (locally up to 1 cm across), scapolite, rare epidote, zircon, embayed amphibole and secondary chlorite are present in some samples.

Less extensive areas of biotite granodiorite gneiss occur at the eastern margin of the map area, associated with hornblende granodiorite gneiss, and adjacent to upper Main River, associated with muscovite granite gneiss.

K-feldspar megacrystic granodioritic gneiss (unit 1p)

K-feldspar megacrystic, medium grained granodioritic gneiss is interpreted to underlie an arcuate area in the eastern part of the region. Although strongly foliated and lineated, the rock is homogeneous except for a few indistinct, concordant quartzofeldspathic veins and elongate amphibolite enclaves. The K-feldspar megacrysts have been flattened to ellipsoidal aggregates. Locally the rock has a more equigranular, granitic aspect and, although probably part of the same body, has been designated as granitic gneiss (unit 1g). Biotite is the main mafic mineral, but accessory garnet and dark green amphibole are also present. Other accessory minerals are apatite, zircon, ilmenomagnetite and rare allanite. No sphene or epidote were observed.

Fine grained muscovite-bearing granodioritic to granitic gneiss (unit 1f)

In the Groswater Bay terrane, unit 1f is associated with unit 1g and is present mostly on the west side of a belt of muscovite-bearing paragneiss and granitoid gneiss in the centre of the map area. The rocks are buff, grey or pink weathering, fine- to medium-grained, muscovite-bearing granitic to granodioritic gneiss. They contain rare biotite schlieren and amphibolite enclaves and are intruded by muscovite-bearing pegmatite. Biotite is the main mafic mineral with lesser muscovite and minor garnet. Allanite, epidote and ilmenomagnetite are ubiquitous accessory phases; epidote and sphene are absent.

Granitic gneiss (unit 1g)

The medium- to coarse-grained granitic gneiss in the central part of the map area is a pale grey, pink or white weathering rock which varies in appearance from homogeneous with discontinuous leucosome partings to well banded, isoclinally folded gneiss. Locally there are extensive homogeneous patches of pegmatoid leucogranite that may represent melt which crystallized after the peak of deformation. These rocks are closely associated with muscovite-bearing metasedimentary gneiss. Major minerals are K-feldspar, plagioclase and quartz with muscovite and/or biotite, and accessory garnet, apatite, zircon and opaque minerals. Trivial amounts of epidote, allanite and sphene are present in the most melanocratic samples and chloritization of biotite is extensive in leucocratic, muscovite-rich rocks.

Some outcrops have been designated 1g/4u in the southern central map area. These are more homogeneous, medium- to coarse-grained, muscovite-bearing granitoid rocks with minor leucosome. Garnet up to 3 cm in diameter occurs in this area.

The arcuate area of granitic gneiss in the eastern part of the map area is a pink weathering, fine- to medium-grained rock that lacks strong fabrics except in southern outcrops, where the rocks are intensely foliated and lineated. Biotite and garnet are ubiquitous mafic phases with trace amounts of allanite, apatite, zircon and opaque minerals. Zircons with rounded cores and euhedral overgrowths appear to be characteristic of unit 1g in this area.

Granitic gneiss at the western end of Double Mer is in the Lake Melville terrane. Stained slabs are fine- to medium-grained, homogeneous microgranite. Mafic minerals are biotite and retrograded hypersthene, and accessory phases are apatite, zircon and ilmenomagnetite. The presence of hypersthene and lack of allanite, epidote and sphene are characteristic of granulite facies rocks in granitic gneiss of the Mount Gnat granulitic belt (a subdivision of the Lake Melville terrane). The rock is closely associated with metasedimentary gneiss and diatexite, and, it is possible that the granitic gneiss in this area is derived from a sedimentary protolith. Similar granitic gneiss occurs south of the map area and has been described by Erdmer (1983, 1984).

Interpretation of unit 1 gneiss in the Groswater Bay terrane

In Figure 6, various gneissic types in the map area have been grouped into subareas. Table 1 summarizes the characteristics of the rocks underlying each subarea which, when considered with overall composition, give each subarea a separate identity. These characteristics probably reflect both primary igne-

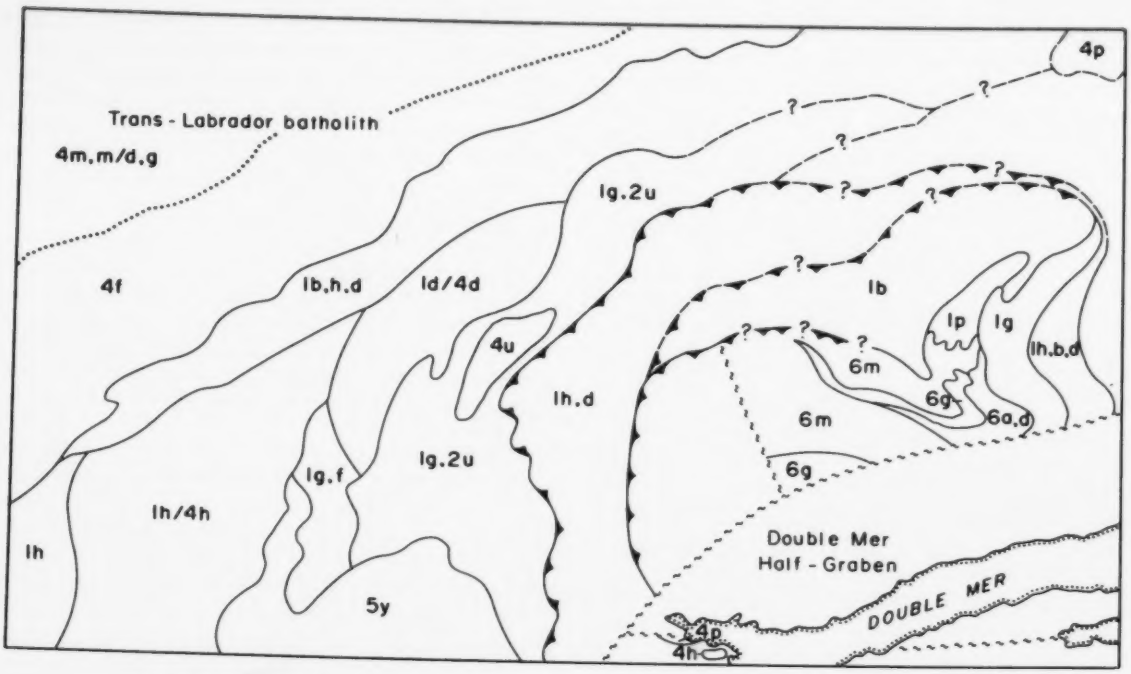

Figure 6. Tentative grouping of granitoid plutons and orthogneiss in the map area; subareas in Groswater Bay terrane are suggested in part to outline former plutons.

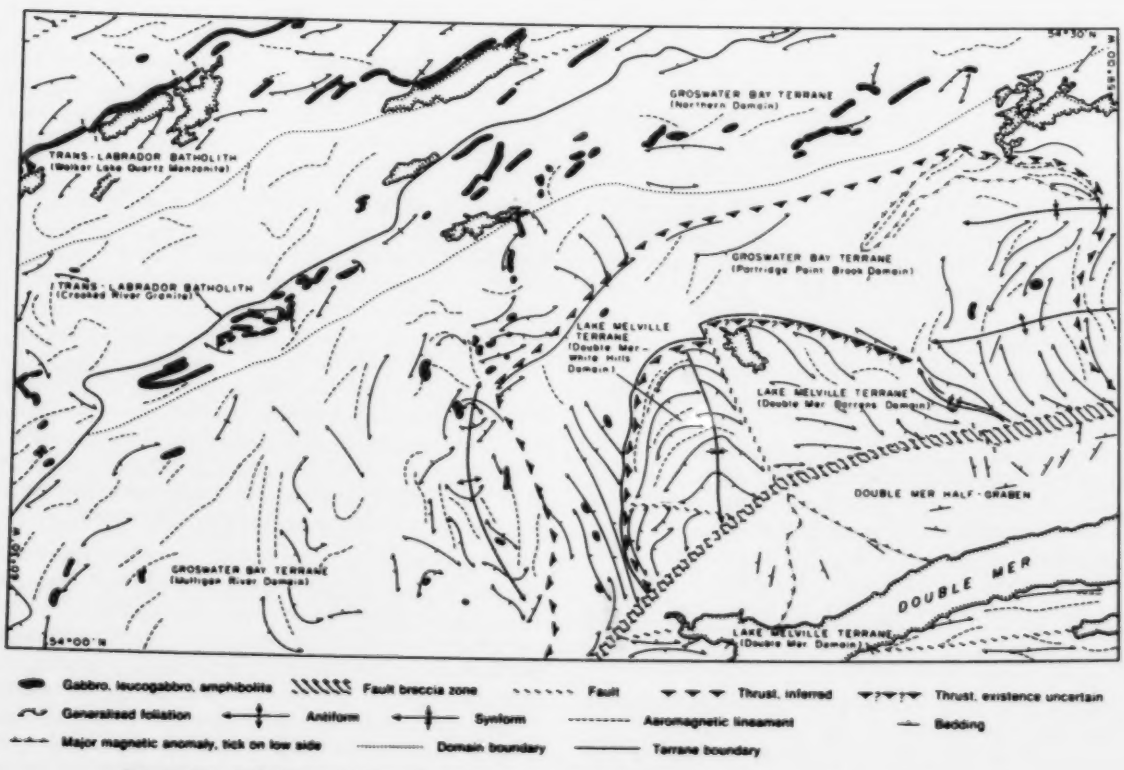

Figure 7. Lithotectonic terranes, domains and other structural features in the map area.

Table 1. Summary of characteristics of grouped gneissic units

1b,h,d (marginal to Crooked River Granite)
Compositionally and texturally heterogeneous, well banded granodioritic gneiss. Biotite is dominant mafic mineral. Hornblende pseudomorphed by biotite + epidote.

1h (extreme southwest of area)
Fine- to medium-grained, well banded granodioritic gneiss. Hornblende pseudomorphed by biotite + epidote. Multiple allanite-epidote growth stages.

1h/4h (headwaters of Mulligan River)
Medium- to coarse-grained, poorly banded granodioritic gneiss. Hornblende pseudomorphed by biotite + epidote. Multiple allanite-epidote growth stages.

1d/4d (centre of area)
Medium- to coarse-grained, poorly banded dioritic gneiss. Melanocratic compared to other gneisses. Locally clinopyroxene- and scapolite-bearing. Allanite and epidote common.

1g,2u (centre of area)
Medium- to coarse-grained, homogeneous to well banded granitic gneiss. Muscovite-bearing; biotite is extensively chloritized. Spatially associated with pegmatoid leucogranite and muscovite-bearing paragneiss.

1g,f (eastern headwaters of Mulligan River)
Fine- to medium-grained biotite granitic gneiss. Muscovite rare. Intruded by muscovite-bearing pegmatite.

1h,d (eastern Main River)
Medium grained, well banded dioritic gneiss. Commonly contains scapolite and garnet. Epidote minor or absent.

1h,d,b (eastern region)
Compositionally and texturally heterogeneous, well banded granodioritic-dioritic gneiss. Hornblende is dominant mafic mineral. Scapolite and epidote also present.

1g (eastern region)
Fine- to medium-grained, poorly banded granitic gneiss, not muscovite- bearing. It contains zircon with rounded cores and euhedral overgrowths.

1p (eastern region)
Medium grained, poorly banded granodioritic gneiss. K-feldspar megacrysts. No sphene or epidote.

1b (north of Double Mer Barrens)
Medium grained, well banded granodioritic gneiss with relict amphibole, rare epidote and sporadic scapolite.

ous features and superimposed metamorphic effects. The following is a somewhat speculative discussion of the possible significance of these subareas. Passing reference is made to some units described more fully in subsequent parts of this report.

The elongate subarea 1b,h,d, which is compositionally heterogeneous and well banded, is interpreted as reflecting complex injection and deformation adjacent to the southern margin of the Crooked River granite. Part of the injected material may have originally come from minor intrusions associated with the Crooked River granite.

The finer grain size and better developed banding in subarea 1h compared to the otherwise similar subarea 1h/4h perhaps can be explained by regarding them as part of the same pluton originally, but 1h having been more severely deformed adjacent to the Crooked River granite. Krogh (1983) has obtained an age of 1680 Ma (U-Pb, zircon) from an outcrop 17 km south of the map boundary on rocks which probably represent the strike continuation of subarea 1h/4h.

Subareas 1d/4d and 1g,2u are both interpreted as outlining former plutons, the northern parts of which have been obliterated and incorporated into unit 1b,h,d. It is possible that subarea 1g,2u continues unexposed as a band toward 4p in the extreme northeastern part of the area. Subarea 1g,f is regarded as a minor variant of 1g,2u. The area mapped as muscovite-rich granite (unit 4u) may be a tectonic eye within the granitic gneiss and pyroxene-quartz syenite to granite (unit 5y) a slightly later pluton.

Subarea 1h,d is probably bounded on both sides by thrusts and may correlate with subarea 1h,b,d in the eastern part of the area. The greater lithological variability of subarea 1h,b,d possibly can be attributed to injection by minor intrusions from an adjacent granite pluton, now represented as subarea 1g.

Subarea 1p is interpreted as a small pluton of K-feldspar megacrystic granodiorite which is possibly a variant of a seriate-textured granodiorite in the adjacent subarea 1b.

Rocks in the outer northern part of the Partridge Point Brook domain (indicated in Fig. 7) show a well developed gneissosity, contrasting with outcrops in interior parts which have a more homogeneous, igneous plutonic appearance. In the Mulligan River domain, a similar pattern of well developed layering in gneisses in the northern fringe areas, as opposed to more homogeneous rocks in the interior of the domain, is also apparent. The conclusions drawn here are as follows; (i) heterogeneous, gneissic regions are bounded on their outer flank by thrusts, (ii) the gneissic fabric is in part produced during thrusting, (iii) complexity of fabric is no evidence of the presence of 'old' gneiss.

Having stated that there is no direct evidence for pre 1680 Ma gneiss in the map area it must also be stated that such rocks may nevertheless exist. Gneiss dated at ca. 2.0 Ga has been found in the southern Trans-Labrador batholith in the Smokey area (Fig. 4; Gower and Owen, 1984a; Owen et al., in press). In addition the quartzofeldspathic character of much of the metasedimentary gneiss suggests the existence of an earlier sialic provenance.

METASEDIMENTARY GNEISS (UNIT 2)

Metasedimentary gneiss occurs in both the Groswater Bay and Lake Melville terranes. The major rock type is pelitic and semipelitic schist or gneiss but psammitic gneiss, calc-silicate rocks and quartzite are common associates.

Most pelitic schist and gneiss in the area has been grouped into one of three units (2u – muscovite-rich; 2k – kyanite-rich; 2s – sillimanite-rich). All three types probably have a similar bulk composition, and subdivision into separate units simply reflects variation in metamorphic grade.

Muscovite-rich pelitic gneiss (unit 2u)

Muscovite-rich pelitic gneiss west of Main River comprises grey weathering, medium grained, quartzofeldspathic pelitic and semipelitic schists. Banding, where present, is defined by a melanosome of muscovite + green biotite ± red garnet, alternating with a coarser grained leucosome of quartz + plagioclase ± microcline. Locally the leucosome is deformed into complex ptygmatic folds (Fig. 8, 9). These schists are interlayered with, and gradational into granitic gneiss (unit 1g).

The extent of two small areas of muscovite schist northwest and north- northeast of Double Mer White Hills has been exaggerated on Figure 5. These rocks are ochrous weathering due to associated pyrite. Minor amounts of other, very weathered sulphides are present, tentatively identified as arsenopyrite and/or chalcopyrite.

Muscovite schist and gneiss in the eastern part of the map area is light weathering, medium grained and has a laminated (in part, mylonitic), foliated or well banded appearance. Locally, these rocks are intruded by pegmatite dykes with muscovite books up to 3 cm across.

Major minerals (noted above) are similar in all these occurrences. In muscovite schist hosted by granitic gneiss,

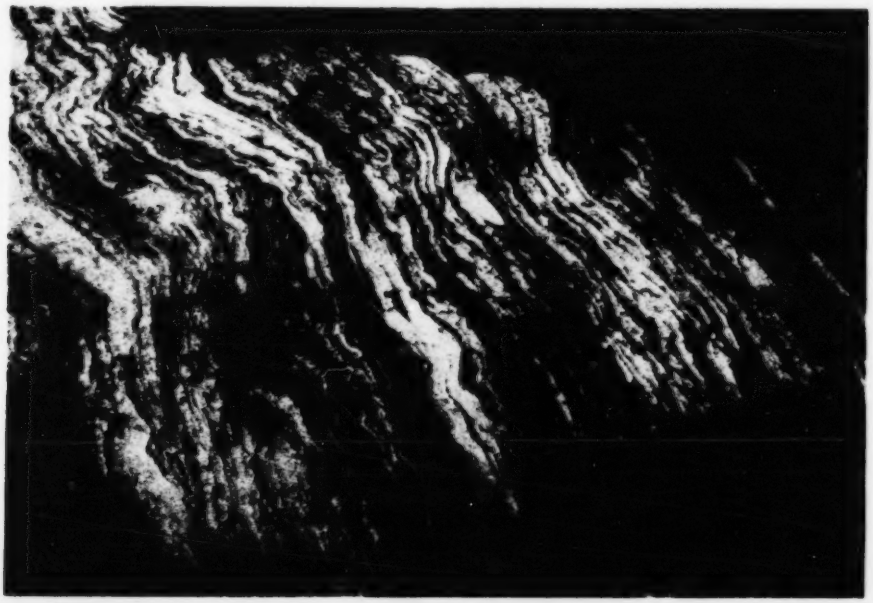

Figure 8. Muscovite-rich pelitic gneiss with interlayered quartz – plagioclase – K-feldspar leucosome, Groswater Bay terrane west of Main River. (GSC 204370)

accessory phases are opaque minerals, apatite and zircon. Muscovite schist associated with hornblende diorite – granodiorite gneiss has epidote and allanite as additional accessory minerals, a feature interpreted as indicating Ca-exchange with host rocks during metamorphism.

Kyanite-bearing pelitic gneiss (unit 2k)

Kyanite-bearing pelitic gneiss occurs in three areas, namely (i) lower Main River, (ii) eastern part of area, (iii) north and west flanks of Double Mer White Hills. The rocks in the first two areas are morphologically similar, being pale pink to black-and-white weathering, medium grained and schistose to gneissose. They are characterized by a kyanite + muscovite + biotite (green and brown) ± red garnet melanosome association with a coarser grained plagioclase + quartz + K-feldspar (microcline and/or perthite) leucosome. Not all rocks have separately developed melanosome and leucosome. Biotitic selvages to leucosome and a phlebitic appearance suggest close to *in situ* partial melting. The kyanite is glassy green and is typically found as recrystallized granular aggregates. In the eastern area, the southern end of the metasedimentary gneiss belt links up with kyanite- bearing rocks in the Rigolet map area (Gower et al., 1983a). The northern continuation is buried by glacial deposits but a marked positive aeromagnetic anomaly (Fig. 5) possibly indicates a subsurface westward extension. The muscovite appears to co-exist stably with kyanite and K-feldspar in some samples but to be a retrograde product in others. Fibrolitic sillimanite, interpreted from thin section evidence to be retrograde, was observed in one sample from the eastern area. Opaque minerals, zircon and rare apatite are minor phases.

Kyanite-bearing metasedimentary gneiss around the north and west flanks of Double Mer White Hills has a flaggy, strongly lineated appearance (Fig. 10) related to extreme deformation associated with thrusting at the edge of the Lake Melville terrane. The rocks are medium grained, well banded and consist of plagioclase + perthitic K-feldspar + quartz + biotite (orange-brown) + kyanite + mauve garnet + sillimanite + opaque minerals + zircon ± hercynite with minor secondary chlorite and white mica. Muscovite is absent. Sillimanite occurs as stable prismatic grains, but is not abundant.

Sillimanite-bearing pelitic gneiss (unit 2s)

Metasedimentary gneiss in which sillimanite is the dominant aluminosilicate has only been found in the southern Double Mer White Hills area. The general field appearance of rocks near the west end of Double Mer suggests that they probably bear sillimanite, but sillimanite was not unequivocally identified. Sillimanite has been recorded in contiguous areas to the southeast (Erdmer, 1983). The pelitic gneiss in the southern Double Mer White Hills is medium grained and pale grey to rusty weathering. The rocks consist of plagioclase + perthite + quartz + orange-brown biotite + mauve garnet + prismatic sillimanite + opaque minerals + zircon ± hercynite ± tourmaline. Some of the sillimanite may have relict kyanite cores. The most extensive sulphide occurrence in the region occurs in these rocks (*see* Economic mineral potential).

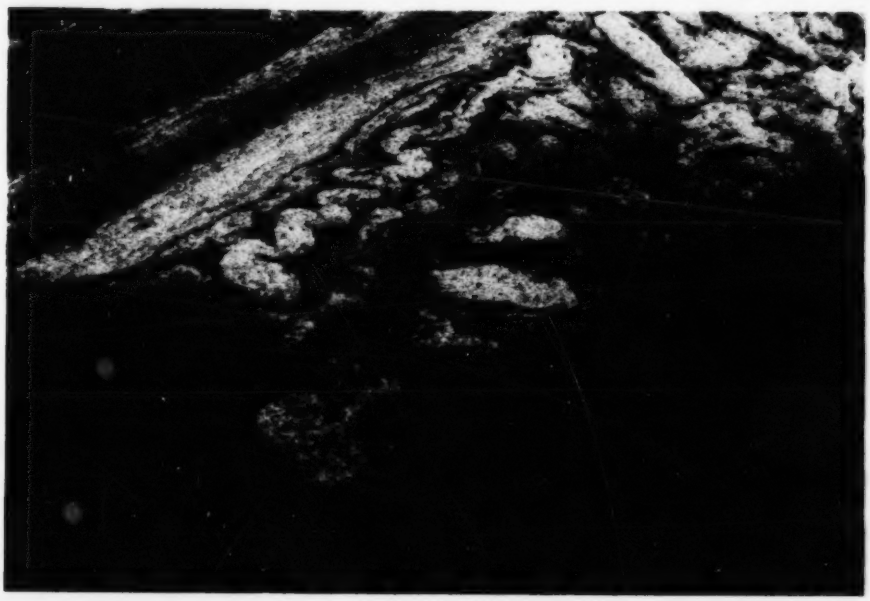

Figure 9. Detail of outcrop shown in Figure 8 showing complex ptygmatic folds in leucosome. (GSC 204370-A)

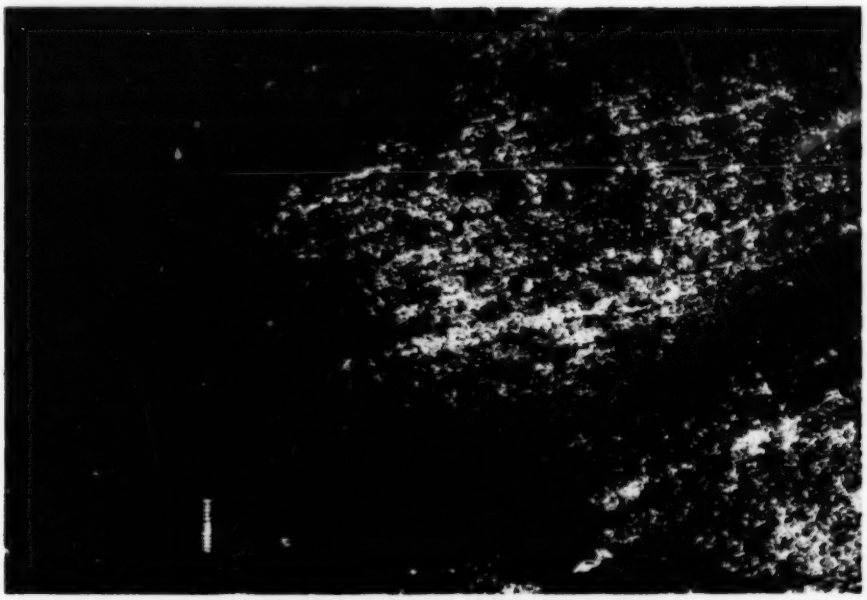

Figure 10. Strongly lineated, flaggy kyanite-bearing pelitic gneiss from Lake Melville terrane, northwest side of Double Mer White Hills. (GSC 204370-B)

Figure 11. Interlayered quartzite and calc-silicate metasedimentary gneiss from Lake Melville terrane, west side of Double Mer White Hills. (GSC 204370-C)

Psammitic gneiss (unit 2w)

Psammitic gneiss accompanies pelitic rocks in most localities, but is especially common with pelitic gneiss in the southern Double Mer White Hills. The rocks differ from the pelites in having hornblende rather than sillimanite and containing more quartz and feldspar. The presence of hornblende is taken to indicate derivation from a calcareous arenite protolith, an interpretation supported by their association with calc-silicate metasedimentary gneiss.

Calc-silicate gneiss (unit 2c)

Calc-silicate metasedimentary rocks were found in three areas; adjacent to Main River, around the north and west flanks of Double Mer White Hills, and in the southern Double Mer White Hills.

Calc-silicate rocks adjacent to Main River were found at only one locality. There, the rock is dark green weathering, layered, medium grained, composed of quartz (30-50%) hornblende, diopside, sphene and opaque minerals with minor epidote, apatite and plagioclase. The layered appearance and high quartz content, in particular, distinguish this rock from normal amphibolite. The protolith was probably a calcareous mudstone.

Calc-silicate rocks around the north and west flanks of Double Mer White Hills are medium grained and commonly have an alternating green and red layered appearance, mainly due to variation in pyroxene and garnet proportions. The complete mineralogy is diopside + plagioclase ± scapolite ± garnet ± green-brown hornblende ± opaque minerals ± quartz ± apatite ± sphene ± brown biotite ± perthitic K-feldspar ± hypersthene. Garnet and sphene do not occur together and biotite, K-feldspar and hypersthene are only found in the most potassic samples, which are gradational into associated pelites. Chlorite and epidote are rare secondary minerals.

The calc-silicate rocks in the southern part of Double Mer White Hills are similar (including a hypersthene-bearing rock) except that sphene was not observed in any sample and, because of close proximity to the Double Mer fault, alteration is more widespread (epidote ± actinolite ± carbonate ± white mica).

Quartzite and quartz-rich psammitic gneiss (unit 2q)

Thin layers of quartz-rich metasedimentary gneiss associated with calc-silicate rock (Fig. 11) or psammitic gneiss were observed in several localities (see 1:100 000 scale map). The most extensive occurrences are on the west flank of Double Mer White Hills, and consist of quartz (greater than 95%), opaque minerals and rare apatite. A few rocks designated unit 1g/2q may have been derived from an arkose but, because these occurrences are not associated with other metasedimentary gneiss and the rocks lack layering, my preferred interpretation is that they are deformed microgranites.

Other units associated with metasedimentary gneiss (units 2a, 2v, 2x)

These are of minor importance in the Double Mer White Hills map area. Unit 2a is amphibolite, probably intrusive in origin, associated with metasedimentary gneiss. Unit 2v is biotite-rich schist (without noteworthy muscovite or aluminosilicates) and unit 2x refers to diatexites associated with paragneiss. No cordierite-bearing rocks (unit 2z elsewhere) were found in the area.

Comments on origin and age of metasedimentary gneiss

The metasedimentary gneiss was derived from a mixed protolith consisting mainly of argillaceous material but with minor calcareous argillite, impure carbonate rock and quartzite.

The age and provenance of the metasedimentary gneiss is uncertain. The rocks are interpreted as either Lower Proterozoic or early Middle Proterozoic because they are associated with, and assumed to have been intruded by, metaplutonic rocks considered to have been emplaced ca. 1.7 to 1.6 Ga. No intrusive contacts were observed, however.

The nearest pre-1.65 Ga supracrustal rocks belong to the Aillik Group. The lower part of the Aillik Group (deposited ca. 1.9 Ga) contains some comparable lithologies but it also has mafic lavas, for which no equivalent has been recognized in the map area. The upper part of the Aillik Group is composed mostly of felsic pyroclastic and epiclastic rocks which also contrast with metasedimentary rocks in the map area. If facies variations are invoked then the metasedimentary gneiss of the map area could be equivalent to either on present knowledge.

In a wider context kyanite- and/or sillimanite-bearing metasedimentary gneiss associated with psammitic metasedimentary gneiss and rare quartzite has been reported within the Grenville Province across the whole of southern Labrador. These have been described (from east to west) by Gower and Owen (1984a), Erdmer (1983), Wardle and Ash (1984), Ryan (1982), Thomas et al. (1981, 1984), Thomas and Wood (1983), Nunn and Christopher (1983), Nunn et al. (1984), Wardle and Britton (1981), Wardle (1982), and Rivers (1983). Radiometric dating (U-Pb zircon, Krogh, 1983) of these metasedimentary gneisses in central Labrador has yielded ages between 1676 and 1645 Ma. These ages have been interpreted as dating high grade metamorphism (Thomas et al., in press). An attempt to date metasedimentary gneiss in the Lake Melville terrane at Sandwich Bay in eastern Labrador gave a Rb-Sr whole-rock errorchron of 1445 ± 220 Ma (Brooks, 1983).

The metasedimentary gneiss appears to be remarkably uniform throughout this region. There are subtle differences, however. Minor, intercalated supracrustal mafic volcanic rock has been reported from west-central Labrador (Nunn et al., 1984) and minor calc-silicate rock is a characteristic, albeit minor, component of the metasedimentary gneiss in eastern

Labrador. Quartzite also appears to be more common in eastern Labrador. It is uncertain at present whether these lithological variations reflect original sedimentary facies variations (assuming that the metasedimentary gneisses are correlative) or simply that some rock types have escaped notice, or are unexposed, in particular regions. The presence of carbonate-quartzite in eastern Labrador, minor mafic volcanics in west-central Labrador and extensive mafic volcanics in the Labrador Trough encourages speculation of increasingly deeper water conditions from shallow-water shelf conditions in the east to slope sequences in central Labrador, to the basinal environment of the Labrador Trough (perhaps around an Archean cratonic nucleus represented by the North Atlantic Craton; Bridgwater et al., 1973). Such correlations, however, are perhaps premature given the complex structural geometry being encountered within the region.

GRANITOID PLUTONS (UNITS 3, 4, 5)

Massive to gneissic fabrics exist within rocks assigned to units 3, 4 and 5. These rocks have been grouped because they occur as coherent bodies that generally do not exhibit marked compositional heterogeneity in outcrop. No age relationships are implied with respect to unit 1. Indeed it is probable that many unit 1 rocks are simply more deformed (and, in part, migmatized) equivalents of units 3, 4 and 5, as previously implied by the unit designation 1h/4h, for example. Units 3, 4 and 5 are probably all similar in age, having been emplaced between 1.7-1.6 Ga. Overall, unit 3 is the least differentiated and unit 5 the most differentiated and, based on limited geochronological data, the hypothesis is adopted that this coincides with their sequence of emplacement.

Quartz monzodiorite (unit 3m/d)

The only occurrence of unit 3m/d in the map area is south of Double Mer in the area compiled from Erdmer (1984). Erdmer described the rock as a medium grained, dense hornblende quartz monzodiorite gneiss with gradational boundaries to enveloping rocks. It is an attenuated extension of the Rigolet quartz diorite mapped by Gower et al. (1983a) farther east.

Walker Lake quartz monzonite (units 4m, 4m/d, 4g)

The Trans-Labrador batholith within the map area (Fig. 4) comprises two contrasting granitoid units. In the north is the Walker Lake quartz monzonite, which is part of the broader Otter Lake – Walker Lake granite (Ryan, 1982). In the south is the Crooked River granite, also defined by Ryan (1982).

The Walker Lake quartz monzonite (unit 4m) is dominantly a pale pink, white or cream weathering, coarse grained rock with compositional variations that include monzodiorite (unit 4m/d) and granite (unit 4g). It is mostly massive but foliated varieties occur locally, especially in southern outcrops. The rock has a seriate to locally K-feldspar megacrystic texture. Mafic enclaves are rare and found mostly within monzodiorite. The lack of mafic enclaves is a contrast to other parts of the Otter Lake – Walker Lake granite (*see* Smyth, 1977; Ryan and Harris, 1978). This may be due to less detailed observation within the present map area, or due to a genuine contrast in enclave abundance, or because separate intrusions have been mapped. Minor granitoid intrusions include buff-pink aplite and microgranite and rare pegmatite.

No age has been determined for the Walker Lake quartz monzonite within the map area, and ages determined for this body elsewhere are not entirely consistent. Gower et al. (1982) summarized age data available to the end of 1981, which collectively indicated an age of ca. 1.6 Ga. Subsequently, Brooks (1983) has reported an age of 1628 ± 9 Ma (U-Pb, zircon) for biotite-hornblende quartz monzonite that previously yielded a 1595 ± 34 Ma (Rb-Sr) errorchron. The quartz monzonite dated by Brooks (1983) may not, however, be the same unit as that underlying the present map area. Kontak reported revised data (personal communication to Ryan, 1983) indicating an age of 1548 ± 73 Ma (Rb-Sr) for the Walker Lake granite at Walker Lake, again not necessarily the same unit as in the map area.

Major mineral phases are plagioclase + K-feldspar + quartz + biotite. All felsic minerals occur as large relict primary grains surrounded by recrystallized aggregates (mortar texture). Primary plagioclase shows normal and oscillatory zoning, commonly emphasized by secondary clinozoisite or white mica. Primary K-feldspar occurs as stringlet perthite but large areas are now microcline, as is all recrystallized groundmass material. Aggregates of biotite, epidote, sphene and opaque minerals have replaced amphibole which commonly occurs as associated ragged blue-green relict grains. Biotite, sphene and opaque minerals are primary in some rocks. Apatite, allanite and zircon are ubiquitous additional accessory minerals and garnet was seen in thin sections from two southern localities. Chlorite after biotite, and white mica after biotite and K-feldspar, are widespread secondary minerals. Kontak (1979) ascribed alteration of feldspars and mafic silicate phases to deuteric phenomena but the extensive recrystallization observed in some samples, local foliation, and presence of garnet (not xenocrystic) is interpreted here as the result of regional greenschist to lower amphibolite facies metamorphism of the Walker Lake quartz monzonite (*see* Metamorphism).

The granitic variant (unit 4g) in the northwest corner of the map area and the more ubiquitous monzodiorite (unit 4m/d) are interpreted as more differentiated products of a parent magma that mostly crystallized to give quartz monzonite. A small body of coarse grained diorite to quartz diorite (unit 4d) occurs within the Crooked River granite. Genetic relationships to the Walker Lake quartz monzonite have not been established.

Crooked River granite (unit 4f)

Buff to pale pink weathering, biotite-muscovite leucogranite underlies a large area between the Walker Lake quartz monzonite and gneissic rocks of the Groswater Bay terrane. These leucogranites are comparable to, and continuous with aplitic granitoid rocks referred to by Ryan et al. (1982) as Crooked River granite.

Figure 12. Enclaves of fine grained (Crooked River?) granite within Walker Lake quartz monzonite. (GSC 204370-D)

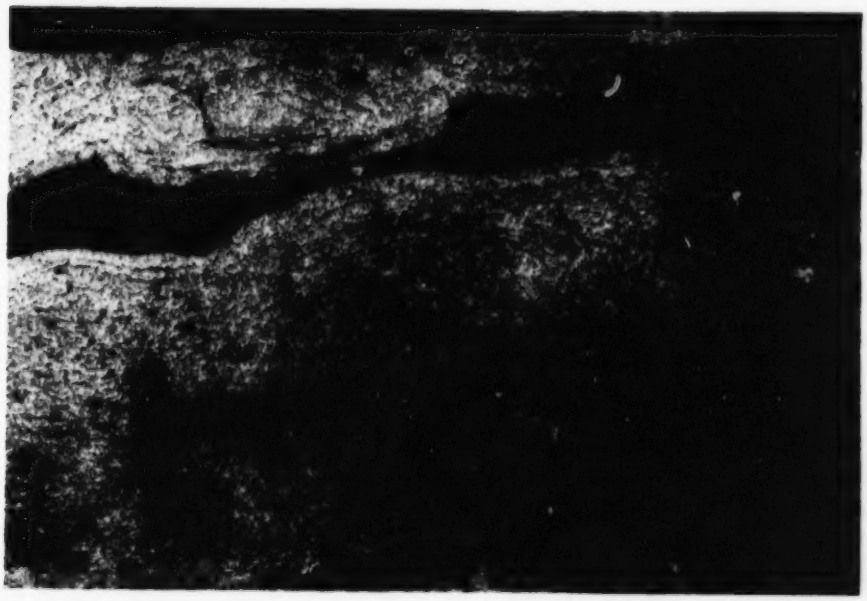

Figure 13. Deformed mafic dyke intruding kyanite-bearing muscovite granite, Groswater Bay terrane, upper Main River area. (GSC 204370-E)

Figure 14. Deformed mafic dyke intruding K-feldspar megacrystic granodiorite, Lake Melville terrane, west of Double Mer. (GSC 204370-F)

The rocks are fine- to medium-grained, typically massive and have a sugary texture, but locally are deformed to muscovite-biotite schist. As noted by Ryan et al. (1982), such fabrics make these rocks difficult to distinguish from arenaceous metasediments, a previously suggested protolith (Williams, 1970). Intrusive contacts with other granitoid rocks, homogeneity over wide areas, and lack of bedding are evidence for a plutonic origin for this unit. Quartz veins, hematized fractures and a lack of mafic enclaves are characteristic of the unit.

The mineralogy of the rock is plagioclase + microcline + quartz with accessory green biotite + muscovite + sphene + apatite + opaque minerals ± fluorite ± clinozoisite/epidote ± allanite ± zircon ± amphibole (one thin section) ± minor secondary chlorite. Small garnets were observed in two thin sections. One of these (from a locality at 54°12′N, 60°25′W) lacks biotite and contains unusually abundant muscovite and could be interpreted alternatively as a muscovite-bearing metasediment within the Groswater Bay terrane as it is very close to the boundary.

Fine grained granite of the Crooked River type is exposed with hornblende-bearing gneissic granodiorite with discontinuous leucosome in an outcrop at 54°29′N, 59°28′W but contacts were not observed. As the fine grained granite shows no evidence in outcrop of the metamorphism and deformation that affected the gneissic granodiorite, this feature is taken tentatively as evidence for tectonothermal activity prior to the emplacement of the Crooked River granite.

At another locality (54°27′N, 60°08′W) enclaves of fine grained granite were found within monzodiorite grouped with the Walker Lake quartz monzonite (Fig. 12). If this fine grained granite is equated with the Crooked River granite, this implies that the Crooked River granite is the older of the two, and conflicts with reverse age relationships interpreted by A.B. Ryan farther west (personal communication, 1983). Possible explanations for this conflict are, (i) either not all Crooked River granite, or Walker Lake quartz monzonite, has the same age, or (ii) the 'enclaves' are an artifact of irregular contacts observed on a flat outcrop.

Muscovite granite (unit 4u)

Muscovite granite at the headwaters of Main River is pale pink, dark pink or creamy grey weathering, and medium- to coarse-grained. Fabric varies from massive to strongly foliated (Fig. 13). Locally the rock is intruded by concordant and discordant pegmatite veins. The borders of the body were not observed and the granitic gneiss envelope may merely be a more deformed equivalent. The rock consists of plagioclase + microcline + quartz + muscovite + green biotite + garnet with accessory apatite, allanite, epidote, opaque minerals, zircon, kyanite (one sample) and secondary chlorite. The kyanite occurs as relict grains largely retrograded to muscovite (*see* Metamorphism).

K-feldspar megacrystic granodiorite (cf. Trans-Labrador batholith) (unit 4p)

Coarse grained, strongly foliated granodiorite with K-feldspar megacrysts up to 4 cm has been mapped in the northeast corner of the map area. The rock has biotite-rich enclaves, narrow biotite microgranite dykes and lacks gneissic banding.

The mineralogy is plagioclase + microcline + quartz + green biotite + relict blue-green hornblende + epidote + allanite + apatite + zircon + sphene + opaque minerals. As granodiorites with large K-feldspar megacrysts are a component of the Trans-Labrador batholith, but appear to be absent in the Groswater Bay terrane, this outcrop is tentatively grouped with the batholith.

K-feldspar megacrystic granodiorite (Lake Melville terrane) (unit 4p)

At the west end of Double Mer, K-feldspar megacrystic granodiorite (also mapped as unit 4p) occurs as a dark pink weathering, strongly foliated rock with megacrysts up to 8 cm long. Mafic enclaves are present and the granodiorite is also intruded by a mafic dyke that predates deformation (Fig. 14). Major minerals are plagioclase, perthite, quartz and chlorite with accessory apatite, epidote, carbonate and opaque minerals. The widespread chlorite, epidote and carbonate are evidence of extensive retrogression, possibly related to a fault bounding the southern side of the Double Mer half-graben. The K-feldspar megacrystic granodiorite correlates with a similar rock type farther east mapped by Erdmer (1983,1984) on the south side of Double Mer.

Hornblende quartz monzonite (unit 4h)

Hornblende quartz monzonite at the west end of Double Mer is pink weathering, coarse grained rock observed at one locality. The mineralogy is plagioclase + perthite + quartz + hornblende + garnet + orthopyroxene + brown biotite + allanite + apatite + opaque minerals + zircon. The orthopyroxene is a relict phase and garnet occurs with hornblende and quartz as coronas between mafic silicates and plagioclase (*see* Metamorphism).

The rock is similar to larger bodies mapped by Gower et al. (1983b) on the south side of Lake Melville except that, in those, granulite facies assemblages have not been recorded.

Mafic rocks associated with granitoid plutons (units 4a, r)

Amphibolite associated with granitoid plutons (unit 4a) occurs as elongate bodies within the Crooked Lake granite, and has been indicated as an alternative unit designator elsewhere. The rocks are foliated/schistose, green, black or brown weathering, and locally injected by irregular quartzofeldspathic veins. The rocks are included with unit 4 because they show metamorphic features which appear to be absent in the surrounding (later?) gabbros (unit 7a).

Gabbroic rocks referred to as unit 4r have textures (especially coarser grain size) and corona mineralogies (*see* Metamorphism) that are anomalous compared to the surrounding gabbros. Because of these differences, it is suspected that they may be unrelated to unit 7 gabbros, and perhaps belong to earlier mafic intrusive activity (cf. Adlavik Intrusive Suite).

Quartz syenite, granite, alkali feldspar granite (unit 5g, 5m, 5y)

Pink, buff, orange-pink or brick red quartz syenite, granite, and locally alkali feldspar granite are distinct rock types in the south-central part of the map area. The rocks grade into quartz monzonite and muscovite granite at the west and north margins of the unit respectively. The pluton was originally coarse grained but has been partly recrystallized to give a medium grained, strongly foliated fabric which merges into an indistinct gneissosity in border areas. Locally the pluton and surrounding gneiss appear to be interleaved.

The rock type was first mapped by Eade (1962) in NTS 1:250 000 sheet 13G and subsequently by Stevenson (1969, 1970) in 13F and 13J. The shape of the unit has been refined during this mapping. South of the present map area, modifications were reported by Erdmer (1983, 1984). Within the map area the main change has been to reassign Stevenson's eastward extension of the unit as gneiss (unit 1h,d). Krogh (1983) has reported a U-Pb (zircon) age of 1632 ± 7 Ma for the unit from samples on the southern boundary of the present map area.

The presence of clinopyroxene makes this rock type unique among the granitoid plutons in the area. It is a relict mineral, having been largely (or in places completely) pseudomorphed by dark green amphibole, bronze green biotite, sphene, and opaque minerals. Felsic minerals are plagioclase, K-feldspar (perthite and microcline) and quartz. Other accessory phases are allanite, apatite, zircon (rounded cores, euhedral overgrowths), garnet, scapolite (one sample), epidote (two samples). Scapolite and epidote occur in samples near the borders of the unit and may be the product of contamination from the surrounding more Ca-rich gneisses.

GRANULITE FACIES FOLIATED TO GNEISSIC PLUTONS (UNIT 6)

Foliated to gneissic plutonic rocks, the majority with diagnostic granulite facies assemblages, occur in three domains in the Lake Melville terrane. These are, (i) Double Mer Barrens, (ii) Double Mer White Hills, and (iii) Double Mer (These domains are indicated on the structural sketch map, Fig. 7).

The rocks in the Double Mer Barrens domain embrace a wide range of compositions, and have been subdivided into six units, in order of decreasing colour index as follows: 6a – mafic granulite, 6d – dioritic granulite, 6m – monzonitic granulite, 6b – granodioritic granulite, 6g – granitic granulite, 6l – leucomonzonitic granulite. The lettering system adopted is a carry-over from that used for lower grade orthogneiss. It is intended to reflect bulk composition, rather than metamorphic assemblages or protolith.

Mafic and dioritic granulite (units 6a, 6d)

The mafic and dioritic granulites include an association of rocks that are variously black, buff or grey weathering, fine- to medium-grained and have a strong to intense foliation and

lineation. The mineralogy is plagioclase + quartz + garnet + hornblende ± clinopyroxene ± scapolite with minor red-brown biotite + opaque minerals + apatite + zircon ± hypersthene ± allanite. The rocks at the east end of Double Mer Barrens appear to be at a lower metamorphic grade and may indicate a transition into lower grade orthogneiss of the Groswater Bay terrane. On the map these rocks have been designated unit 6/unit 1.

Units 6a and 6d are interpreted as derived from gabbro, leucogabbro, anorthosite and diorite. It is possible that they are remnants of a former layered mafic intrusion, however, on present knowledge, it is equally likely that entirely genetically disparate rocks have been included.

Granodioritic, monzonitic and granitic granulite (units 6b, 6m, 6m/b, 6g)

The granodioritic, monzonitic and granitic granulites are grey, white or locally pink weathering, medium- to coarse-grained rocks with marked foliation and lineation. The granodioritic granulites (unit 6b) are mostly confined to the southern part of Double Mer Barrens; farther west, along strike, most outcrops are quartz-poor, K-feldspar-rich monzonite (unit 6m); in the north the dominant composition is between quartz monzonite and granodiorite (unit 6m/b); locally these latter rocks are sparsely megacrystic. The granitic granulites, (unit 6g) occur in a narrow zone mostly within pink weathering, generally fine grained rocks, and are intensely foliated and lineated. They grade into mylonite and it is possible that the linear zone of granitic granulite marks a thrust.

Minerals present in these three units include plagioclase + perthite + quartz + green-brown hornblende + garnet ± hypersthene ± clinopyroxene with minor red-brown biotite + opaque minerals + apatite + zircon ± allanite. In all felsic granulites, orthopyroxene and clinopyroxene are most abundant in the central and western parts of Double Mer Barrens. In the eastern area, orthopyroxene is lacking (or is a dubious bastite pseudomorph) and clinopyroxene is sporadic.

Figures 5 and 6 suggest equivalence between unit 6m/b and K-feldspar megacrystic granodiorite (unit 1p). The two units do have textural similarities, but stained slabs show mineralogical differences. These may be attributable to differences in metamorphic grade (*see* Metamorphism).

Leucomonzonitic granulite (unit 6l/m)

In the Double Mer White Hills domain leucomonzonitic granulite occurs in two separate, lithologically similar sheets. The northern sheet is underlain and overlain by metasedimentary gneiss and is estimated to be roughly 2 km thick. The southern sheet is only preserved capping hill tops and its thickness is unknown.

The rock type is remarkably uniform over its entire outcrop area. Both sheets are essentially identical in composition and texture, except adjacent to the Double Mer fault where they are brecciated and partially altered to greenschist facies assemblages.

The leucomonzonitic granulite is brownish grey, cream, buff or white weathering and has been thoroughly

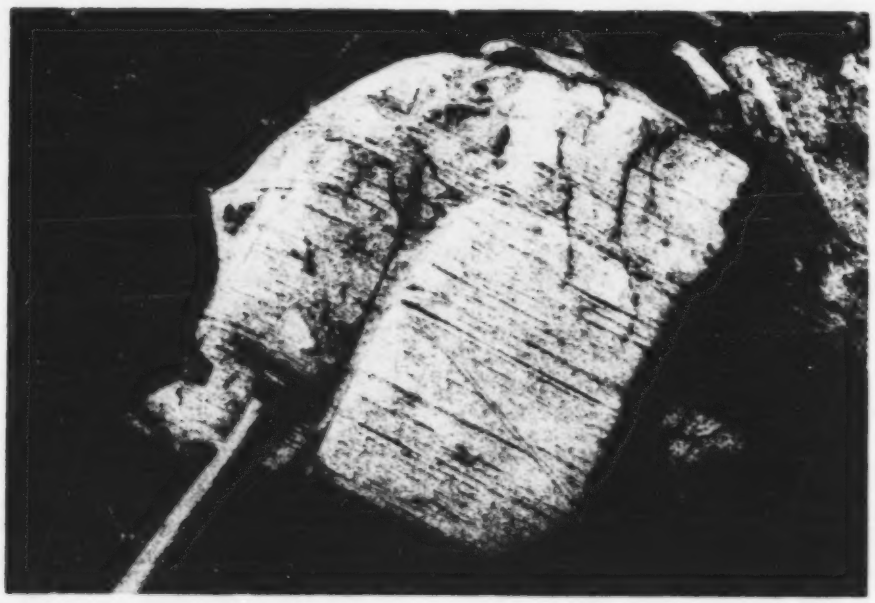

Figure 15. Leucomonzonite granulite, Lake Melville terrane, Double Mer White Hills. (GSC 204370-G)

recrystallized to a fine or medium grain size. The rock has a streaky, layered appearance (Fig. 15), due to extremely elongate lenses of mafic material and rare concordant microgranite layers, locally isoclinally folded. It has an intensely foliated and lineated fabric, but is not gneissic, and there can be no doubt that it has been extremely flattened. This fabric is truncated by discordant rectiplanar pegmatite in places.

The same mineralogy applies to all samples examined, namely plagioclase + perthite + quartz + hypersthene + clinopyroxene + minor green-brown hornblende, opaque mineral, apatite, garnet and very rare biotite.

Staining for potassium shows this white weathering rock to be rich in K-feldspar. The rock is finer grained and contains much less garnet than the monzonitic granulite farther east (unit 6m).

MAJOR MAFIC INTRUSIONS (UNIT 7)

Within the southern Trans-Labrador batholith and Groswater Bay terrane in eastern Labrador two major suites of mafic intrusions have been identified, as well as several phases of mafic dykes (Gower, 1984; Gower and Owen, 1984a). The major periods of mafic activity, from the present geochronological data, appear to have occurred at ca. 1650-1600 Ma (*cf.* Adlavik Intrusive Suite) and ca. 1400 ma (*cf.* Michael gabbro). It is difficult, especially in inland areas, to be certain to which intrusive suite a particular rock should be assigned, hence all outcrops are designated as unit 7 on the map, except for a few instances where unit 4r has been used.

Within the Walker Lake quartz monzonite, gabbroic rocks fall into two main groups; a northern, continuous sheet and a southern discontinuous sheet. Minor discontinuities in the northern sheet are interpreted to be due to fault offset. Gabbroid rocks are less abundant in the Crooked River granite. The three mafic bodies closest to the northern border of the Crooked River granite are biotite-bearing amphibolites. Gower (1984) suggested that, because these lack ophitic texture, they might be genetically distinct from the surrounding gabbros. Subsequent petrographic studies, however, indicate that they are probably retrograde equivalents. A cluster of three mafic bodies in the south-central part of the Crooked River granite have very coarse 'appinitic' textures, which Gower (1984) noted as a feature of the 1650-1600 Ma suite. A sample from this group shows corona textures that are anomalous compared to the surrounding rocks (*see* Metamorphism).

Within the Groswater Bay terrane the gabbros occur as resistant ridges or isolated hills above the surrounding drift-covered terrain. Continuity of outcrop decreases southward, as does gabbro abundance (*see* Structure). The rocks are black to brown weathering, medium- to coarse-grained and show obvious ophitic texture. Chilled margins were observed in gabbro adjacent to Walker Lake quartz monzonite.

Unit 7 has been divided into four groups; 7r – coronitic metagabbro, 7a – retrograde metagabbro, 7u – ultramafic rocks, and 7l – leucogabbro. Unit 7r, although referred to as metagabbro, also includes troctolite and noritic gabbro. The primary mineralogy is olivine + plagioclase + clinopyroxene + biotite + opaque minerals + apatite + minor K-feldspar with orthopyroxene or olive-green hornblende as uncommon major phases in some rocks. This mineralogy changes progressively southward through a sequence of corona-textured rocks to a two-pyroxene garnet granulite in those metagabbros close to the Lake Melville terrane. The rocks have been divided into seven types, and where thin section data are available have been denoted by number on the map (*see* Metamorphism).

The retrograde metagabbros (unit 7a), in less altered examples show textures that suggest that they were also once coronites. These rocks are discussed more fully under 'Metamorphism'.

Ultramafic rocks are rare in the area, and only five outcrops have been designated as unit 7u. Two widely separated outcrops occur in the northern part of the Groswater Bay terrane; and the other three are close together, in the area east of lower Main River in the southern part of Groswater Bay terrane and probably originally part of the same unit.

The two northern examples are black weathering and medium- to coarse-grained. Both have an essentially primary mineralogy. One comprises olivine + orthopyroxene + primary amphibole + phlogopitic mica + minor plagioclase + opaque minerals. The other is similar, but lacks primary orthopyroxene. In both, the olivine is partly altered to secondary hypersthene + opaque minerals. Poorly developed coronas of orthopyroxene are present in one, with an amphibole + spinel corona also developed in the other. Both rocks have textures that suggest crystallization from a hydrous gabbroic magma (*cf.* Clark, 1979).

The three southern outcrops, although close together, have different mineralogies. One contains orthopyroxene + clinopyroxene + phlogopitic mica + amphibole + opaque minerals. Another lacks clinopyroxene and phlogopitic mica, but contains olivine and abundant hercynite and a much higher proportion of opaque minerals. A sample from the third outcrop was not thin sectioned. In contrast to the primary igneous textures of samples from the northern outcrops, the southern rocks have textural features of high grade metamorphic rocks.

The leucogabbro (unit 7l) also has coronitic textures and differs from unit 7r only because of its lower colour index.

MINOR GRANITOID INTRUSIONS (UNIT 8)

Unit 8 refers to minor granitoid intrusions, namely microgranite, aplite and pegmatite. The unit includes both rectiplanar and buckled intrusions but excludes highly deformed leucocratic granitoid intrusions closely associated with gneissic rocks. The unit undoubtedly includes intrusions of various ages. For example, minor intrusions associated with the Walker Lake quartz monzonite (unit 4m) are almost certainly genetically part of that plutonic unit, whereas those sheets intruding the later gabbros clearly are not. The only reason for designating them as unit 8 is because some postdate unit 7 whereas none have been observed in unit 9 or above.

MINOR MAFIC INTRUSIONS (UNIT 9)

Minor mafic intrusions (unit 9) were recorded at three localities in the map area. The host rock and locations are; (i) muscovite – kyanite granite in the upper Main River area (Fig. 13), (ii) monzonite granulite at Partridge Point Brook near the Double Mer fault, and (iii) K-feldspar megacrystic granodiorite at the west end of Double Mer (Fig. 14).

The intrusions occur as narrow, buckled dykes less than 30 cm wide. The mineralogy from the first and second locations respectively, is (i) plagioclase + green biotite + epidote with minor apatite, allanite and opaque minerals, and (ii) hornblende + plagioclase + epidote + chlorite + sphene. The age relationships to other mafic rocks is unknown, and the only time constraint is that they postdate granitoid plutons. Although the rocks show greenschist to lower amphibolite facies metamorphic assemblages, it cannot be claimed that this is evidence that they necessarily escaped the granulite facies metamorphism experienced by their host rocks, as two of the dykes are close to fault-deformed rocks in which high grade metamorphic assemblages have been severely retrograded and the third intrudes a kyanite-bearing granite which is itself extensively retrograded.

FAULT BRECCIA AND ASSOCIATED ROCKS (UNIT 10)

While fault breccia is not a lithological unit in the same sense as the preceding rock types described, it is convenient to group fault breccias as a separate rock type. The variable brecciation and alteration experienced by many of these rocks means that designation of an outcrop simply in terms of either a prefault rock type or a shear zone structural symbol is either inadequate or misleading. Thus, unit 10 should be interpreted as a 'flag' indicating fault-deformed rocks, with any other units indicated as a tentative field identification of the prefault rock type at that locality.

Fault breccias occur mainly in two areas; (i) as a major 0.5 to 1.0 km wide belt flanking the north side of Double Mer half-graben, and (ii) in scattered outcrops, roughly aligned north-south, west of Lower Main River.

In both cases the pre-existing rock type has been affected by deformation in a brittle fracture regime with associated low grade alteration. The rocks are pink-red, yellow-green, dark green or white weathering depending on the dominant secondary mineral (hematite, epidote, chlorite or quartz respectively). The effects of alteration may be either pervasive or confined to irregular or anastomosing veins, locally contorted or slickensided. In many cases, the prefault rock type can be interpreted as the deformed equivalent of that immediately adjacent to the fault zone. Some prefault rocks, especially west of Main River, are fine- to very fine-grained, laminated mylonites which clearly indicate an earlier ductile deformation. The distribution of fault- deformed rocks west of Main River with respect to topography suggests a low-angle east-dipping fault.

DOUBLE MER FORMATION (UNIT 11)

The Double Mer Formation underlies a low-lying coastal plain, up to 12 km wide on the north side of Double Mer. The

Figure 16. Medium scale cross-stratification in Double Mer Formation, Double Mer half-graben. (GSC 204370-H).

formation was first named by Kindle (1924) and subsequently mapped by Stevenson (1970). The present distribution of outcrop shown on the map differs from that of Stevenson only at the west end of Double Mer. There, the positions of bounding faults have been changed on the basis of field observations of fault breccia and correlation with structures in the adjoining area to the south.

The Double Mer Formation consists of orange, red, pink or maroon weathering, arkosic sandstone (unit 11s) with subsidiary conglomerate (unit 11o). Shale locally forms a minor constituent within the sandstones. The sandstones commonly show medium scale cross-stratification in sets ranging up to 30 cm thick (Fig. 16). Scour surfaces are common and beds of planar lamination and thin stratification up to 30 cm also occur. The interbedded shales are most common in the central and western areas and conglomerate occurs mainly in the east and locally in the north. Clasts in the conglomerate include a variety of rounded to angular quartzofeldspathic and mafic metamorphic rocks and minor vein quartz. No clasts of supracrustal rock were seen in any outcrop of Double Mer Formation. Clasts range in size from small pebbles to cobbles, with clast size generally increasing from west to east.

The arkose consists mostly of clouded plagioclase, microcline and perthite K-feldspar and common quartz with lesser muscovite flakes, chloritic patches (probably after mafic silicates), opaque minerals, oxidized biotite, apatite, garnet and zircon. The opaque minerals, garnet and zircon define heavy mineral laminations, but opaque minerals also occur as disseminated grains. Rock fragments, mostly composite quartz-feldspar grains derived from a metamorphic-plutonic rock provenance, are common. The arkose is mostly grain-supported with matrix material being mostly smaller quartz and feldspar particles in a pervasive hematite cement. The rocks are moderately sorted with subrounded to angular grains. The best sorted rocks have well rounded grains and are found associated with shales at the western end of Double Mer. These siliciclastic rocks are interpreted as terrestrial sediments that were probably deposited by gravelly and sandy braided streams with fanglomerates in proximal areas. The presence of conglomerate and more immature arkose in eastern and northern areas perhaps suggests westerly transport, although Stevenson (1970) noted that crossbedding directions and imbrication in pebbles suggests derivation from the south. Strata of the Double Mer Formation are clearly associated with a system of graben faults (*see* Structure). The age of the formation is unknown, except that it postdates the Grenvillian Orogeny. It is unfossiliferous and is not crosscut by later intrusions (except quartz veins, marginal to faults). Previously it has been assumed as Late Proterozoic or Cambrian in age (Stevenson, 1970) and tentatively compared with other Late Proterozoic successions (Young, 1981).

STRUCTURE

Trans-Labrador batholith

The area underlain by the Walker Lake granite appears to be structurally simple (Fig. 7). The granitoid rocks are massive or show a weak east-northeast-trending foliation which generally dips within 5° of vertical. All shallower dips are inclined southeast. The foliation distribution is inhomogeneous with large areas of massive quartz monzonite between local foliated zones which may be accompanied by greenschist facies alteration. The east-northeast-trending, south-dipping foliation and inhomogeneous strain are probably related to Grenvillian deformation.

In the Walker Lake quartz monzonite, faulting in two directions is inferred. East-northeast shear zones, accompanied by retrograde alteration were recognized in two places. Northwest-trending faults have been interpreted to explain offsets along the gabbro sheet.

The position of the boundary between the Walker Lake quartz monzonite and the Crooked River granite is only approximately known from outcrop data, but has been drawn to coincide with a well defined aeromagnetic trough which separates regionally higher aeromagnetic fields over the Walker Lake quartz monzonite from lower values in the Crooked River granite. Strongly foliated and lineated rocks near the eastern end of the contact suggest a faulted boundary but enclaves of fine grained granite (tentatively correlated with the Crooked River granite) in Walker Lake quartz monzonite farther west, imply intrusive relationships.

Foliation orientations in the Crooked River granite are less consistent than in the Walker Lake quartz monzonite, and are perhaps related to folding, for which there is indirect evidence. The arcuate form of a gabbro sheet emplaced into Crooked River granite near the western margin of the map area is interpreted as a fold closure which must also have affected the host granite. The fold axis defined by the gabbro sheet can be extrapolated westward through Bathtub Lake (unofficial name, 54°13′N, 60°17′W). This, in turn, requires a folded contact with the Groswater Bay terrane, and is the reason for the S-bend in the boundary in that area.

Groswater Bay terrane

The Groswater Bay terrane is divided into three domains (Fig. 7, revised from Gower, 1984).

The northern domain of the Groswater Bay terrane is characterized by east-northeast-trending metagabbro ridges, in contrast to metagabbro with north or northeast trends farther south. Foliation attitudes in the host gneiss adjacent to metagabbro are variable, but the few outcrops that are remote from gabbro have east-northeast trends. The poor exposure obscures what is probably a zone of extreme complexity, a view suggested by gabbro distribution (see later). The boundary between the Trans-Labrador batholith and Groswater Bay terrane is possibly a thrust, an interpretation endorsed by A.B. Ryan (personal communication, 1983) for the comparable boundary farther southwest.

The Mulligan River and Partridge Point Brook domains have foliation attitudes and rock unit distributions that suggest complex structures resulting from fold interference. The interpretation advanced here is that the pre-Grenvillian tectonic grain was north to northeast and was subsequently overprinted by east-northeast Grenvillian structures. For example, at the eastern edge of the area, an open east-trending (Grenvillian) antiform-synform pair has folded orthogneiss

and paragneiss with north-trending fabrics. Not all north-trending structures, however, need be pre-Grenvillian. A north-trending elongate domal structure is indicated in the south-centre of the map area. The axis of this fold is sub-parallel to the Lake Melville terrane boundary thrust, assumed of Grenvillian age, and hence may have formed during the same deformation.

The north-trending 'tail' on the west side of unit 5y, and a complimentary tail (reinterpreting boundaries from the distribution of outcrop shown by Erdmer (1983) outside the map area farther south) could be taken to indicate anticlockwise rotation of the plutons. Without better knowledge of the pluton outline and detailed structure, however, this suggestion must be regarded as speculation.

The boundary between the Mulligan River and Partridge Point Brook domains is interpreted as a thrust. East and northeast of the boundary, foliation trends in granitic gneiss (unit 1g) are truncated by trends in dioritic gneiss (units 1h, 1d). Along the southern part of the same lithological interface, mylonite (subsequently brecciated and altered – see earlier) was recorded. The grade of metamorphism also differs on either side of the boundary.

An important question, especially relevant to the northern domain of the Groswater Bay terrane, is whether the isolated hills of gabbro are the exposed parts of a subsurface continuous gabbro sheet, with presently unexposed areas having been eroded and covered as a result of glaciation, or else the present outcrop genuinely reflects isolated bodies of gabbro. The former interpretation was adopted by Fahrig and Larochelle (1972), and Emslie (1983), who both depicted the gabbro as anastomosing sheets. In consideration of the opposing viewpoint, the following features are noteworthy: (i) there is a decrease in topographic continuity of exposed gabbro progressively southward, (ii) there is evidence of complex folding (one fold closure has a north-trending fold axis in the north-centre of map area), and (iii) many gabbro bodies exposed on the shore of Groswater Bay (outside the map area) exhibit severely deformed and boudinaged margins. Therefore, the distribution of gabbro on the sketch map may well reflect bedrock distribution, entertaining the hypothesis that the bodies are 'megaboudins' formed during Grenvillian deformation. The foliation attitudes in gneiss adjacent to gabbro are then explained as due to influence from the adjacent boudin. The increasing isolation of metagabbro bodies progressing southward is interpreted as the result of segmentation and separation of originally continuous sheets during high strain deformation.

Lake Melville terrane

The boundary between the Lake Melville and Groswater Bay terranes on the north and west flanks of Double Mer White Hills is interpreted as a thrust. The evidence is as follows: (i) the trend of Groswater Bay diorite-granodiorite gneiss is truncated by trends in the Lake Melville terrane, and (ii) the rocks in the Lake Melville terrane exhibit an intense, south-plunging stretching lineation (Fig. 17), absent in adjacent

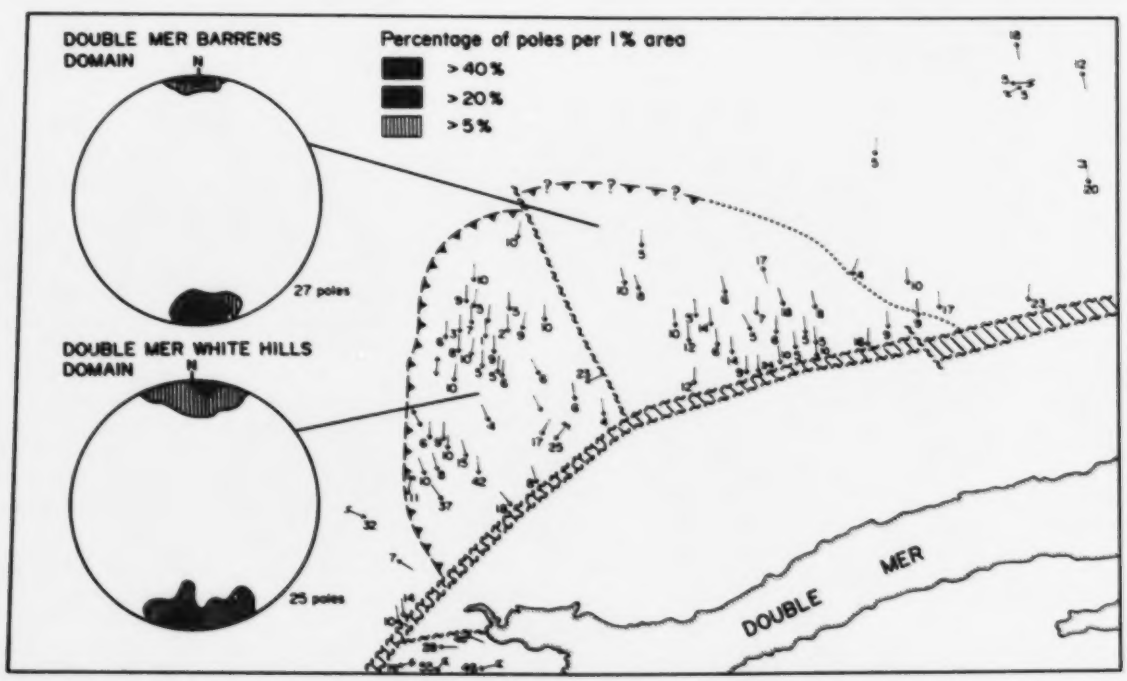

Figure 17. Lineations and minor folds in Lake Melville terrane, and adjacent areas. Lineations are plotted on the lower hemisphere of a Lambert equal-area stereonet.

Groswater Bay gneiss. There are also marked contrasts in rock type on either side of the thrust and a sharp topographic break along its proposed site.

Lithological identity of the two sheets of leucomonzonite granulite and the lithological similarity of two layers of paragneiss may indicate fault repetition within the domain.

The rocks in the Double Mer White Hills domain have been folded into a south-plunging synform. This structure was first depicted by Stevenson (1970) and the change from Stevenson's south-southwest plunge to the south plunge shown in Figure 7 merely reflects additional data. The stretching lineation is also south-plunging, and unaffected by location around the synform; the thrusting, synform development and lineation are interpreted in terms of sheath fold-type flow deformation.

The eastern and southern sides of the Double Mer White Hills domain are bounded by faults related to Double Mer graben formation.

The Double Mer Barrens domain is included with the Lake Melville terrane on metamorphic criteria, but no clear-cut boundary with the Groswater Bay terrane was recognized. In Figure 7, the boundary is indicated as partly a thrust and partly located along the axial trace of an interpreted recumbent synform with a shallowly south-dipping axial surface. Figure 18 attempts to illustrate this structure with increasing displacement along the thrust implied farther west. The structure is consistent with all available geological data but must be regarded as tentative because (i) the distribution of rock units that define the hinge zone is inferred almost entirely from helicopter spot-checks, and (ii) the structurally complex folding expected at the hinge zone was not observed. (However, this is one of the few locations in the map area where sufficient outcrop exists to make further field work warranted.) The attitude of foliations within the Double Mer Barrens domain suggests that it is the east half of the synform in the Double Mer White Hills domain but contrasting lithologies between the two areas denies direct relationships.

Only a small area of the Lake Melville terrane, at the west end of Double Mer, was examined during the present project, but this is continuous with Lake Melville terrane mapped by Gower et al. (1983a) and Erdmer (1983, 1984). The rocks are characterized by well defined east-trending foliations, consistent with a marked east-trending aeromagnetic and topographic 'grain'. Foliation dip directions are not consistent and numerous small scale isoclinal folds were observed at the west end of Double Mer; major, tight folds are, therefore, suspected.

Double Mer half-graben

The area underlain by the Double Mer Formation is interpreted as a half-graben, bounded on the north by a major fault (Fig. 19). The fault is indicated by brecciated, sheared and mylonitized rocks, low grade alteration, a marked topographic scarp and contrasting aeromagnetic patterns. The 'fan' of two faults on the north side (Fig. 20) probably is a related structure, perhaps formed in response to the change in trend of the Double Mer Fault. The presence of mylonite as brecciated blocks, pervasively altered to greenschist facies assemblages and enveloped by low grade shear zones implies two contrasting deformational regimes and is interpreted to mean that the Double Mer Fault was the site of a pre-existing thrust, which was reactivated as a normal fault when the Double Mer half-graben was formed. As neither the mylonite nor the breccia have been dated, however, the hypothesis that both are related to repeated normal movement along low-angle listric faults, cannot be discounted.

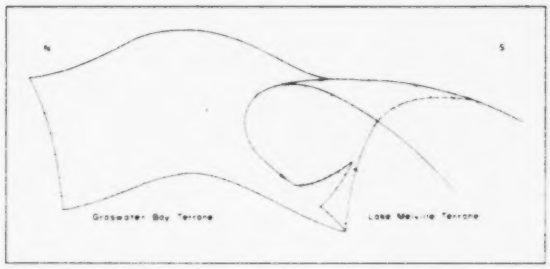

Figure 18. Interpretation of the structural configuration between the Groswater Bay terrane and Lake Melville terrane in the eastern part of the map area.

The southern contact between the Double Mer Formation and the underlying gneiss is unexposed. If it is a fault, as has been depicted on the 1:100 000 map, it is certainly not of comparable magnitude to the fault along the northern contact. Aeromagnetic patterns suggest a north-sloping base of the Double Mer Formation. An aeromagnetic high near the west end of Double Mer (Fig. 19) is interpreted as a basement culmination. Bedding directions in the Double Mer Formation dip away from this high; whether this reflects folding or a pre-Double Mer Formation erosional irregularity is unknown.

The half-graben containing Double Mer Formation within the map area is part of a much larger system of post-Grenvillian fault-bounded basins. These are interpreted in Figure 20.

METAMORPHISM

Metamorphic mineral assemblages are considered in three broad groups; (i) muscovite- and/or aluminosilicate-bearing granitic and pelitic gneiss, (ii) amphibole-bearing quartzofeldspathic rocks, and (iii) coronitic metagabbroid rocks. Brief reference is also made to other rock types.

In each of the principal rock groups three metamorphic zones can be recognized. These are amenable to further subdivision within individual rock groups. Discussion of metamorphism in terms of these groups is a first level effort to minimize mineral assemblage variations due to compositional factors, but the grouping, because of the reconnaissance nature of the project, is by no means as restrictive as desirable.

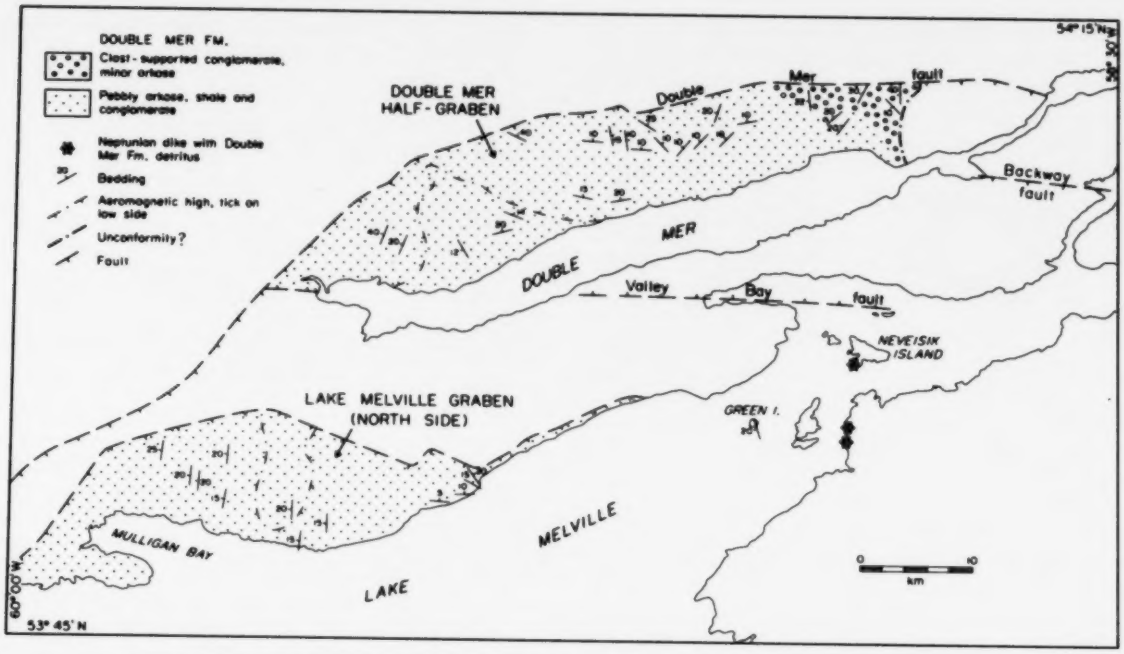

Figure 19. Structural attitudes in the Double Mer half-graben and northern Lake Melville graben. Distribution of Double Mer Formation outside map area is taken from Gower et al. (1983a,b) and Erdmer (1984).

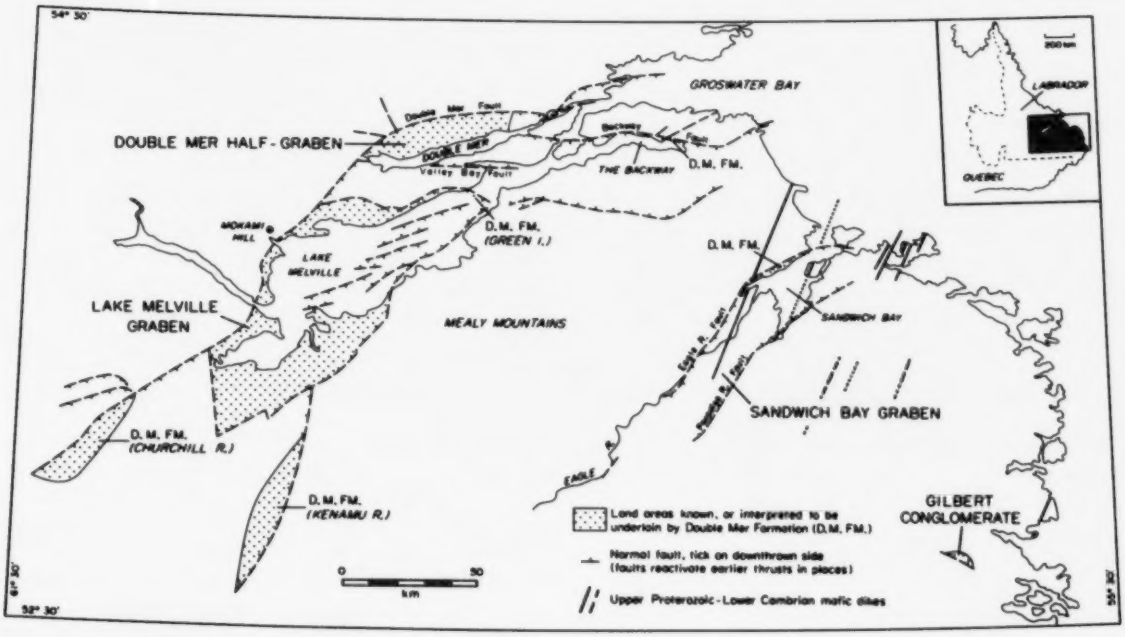

Figure 20. Interpretation of areas underlain by Double Mer Formation and related fault system in eastern Labrador.

Muscovite- and/or aluminosilicate-bearing granitic and pelitic gneiss

The following (indirect) composition constraints have been adopted for this group, (i) all samples contain muscovite and/or aluminosilicate, and (ii) all samples, except as indicated on Figure 21, contain quartz + plagioclase + K-feldspar + biotite. These constraints allow inclusion of units 4g, 4f, 4u, 1g, 2u, 2k, and 2s. Most of the granitoid rocks are in the north and pelitic rocks in the south, a factor which may have some influence on the zonation observed. Progressive changes in mineralogy are summarized in Table 2, and mineral assemblages in Table 3.

Although zone 1 has been subdivided into six subzones on the basis of mineralogy in coronitic metagabbros, the only comparable subdivision seen in muscovite/aluminosilicate-bearing rocks is between zones 1.1 and 1.2 (Fig. 21). In that chlorite is associated with white mica, and garnet is lacking in the extreme northwest part of the Walker Lake quartz monzonite, this region is tentatively designated a separate subzone (zone 1.1). Textural relationships are, however, equivocal and both phyllosilicates may be retrograde. Zone 1.1 rocks have been partly recrystallized from rocks with igneous plutonic textures.

Zone 1.2 is marked by the appearance of garnet, giving the widespread mineralogy quartz + plagioclase + biotite + muscovite + garnet ± K-feldspar. The K-feldspar and some of the plagioclase are interpreted as relict igneous phases. Garnet is first seen in two southerly outcrops of Walker Lake quartz monzonite (only one is plotted on Figure 21, because muscovite is absent in the other), and two samples of Crooked River granite. The garnets are small (less than 0.5 mm), and have irregular amoeboid/skeletal forms, typical of early stages of nucleation and growth. This crystal form, coupled with the fact that they straddle grain boundaries makes a xenocrystic or igneous origin improbable, and hence they are interpreted to have resulted from prograde metamorphism. Inadequate data prevent documentation of specific reactions that control the appearance of garnet but lack of chlorite in garnet-bearing rocks suggests that it is an important reactant.

The reaction that generates garnet occurs farther north than the first appearance of leucosome-bearing gneissic rocks. The appearance of leucosome may indicate the onset of partial melting during prograde metamorphism, but the possibility that it was produced during an earlier cycle of melt generation cannot be excluded.

Zones 1.3 to 1.6 cannot be discriminated from zone 1.2 on the basis of mineralogy contrasts in muscovite-bearing rocks. Garnet in zones 1.3 to 1.6 is more common than in zone 1.2. It occurs as crystals (generally between 1-10 mm), has a subhedral to euhedral habit, and is locally, but not extensively, poikiloblastic. A leucosome fraction is associated with most gneissic rocks in the southern half of zone 1.

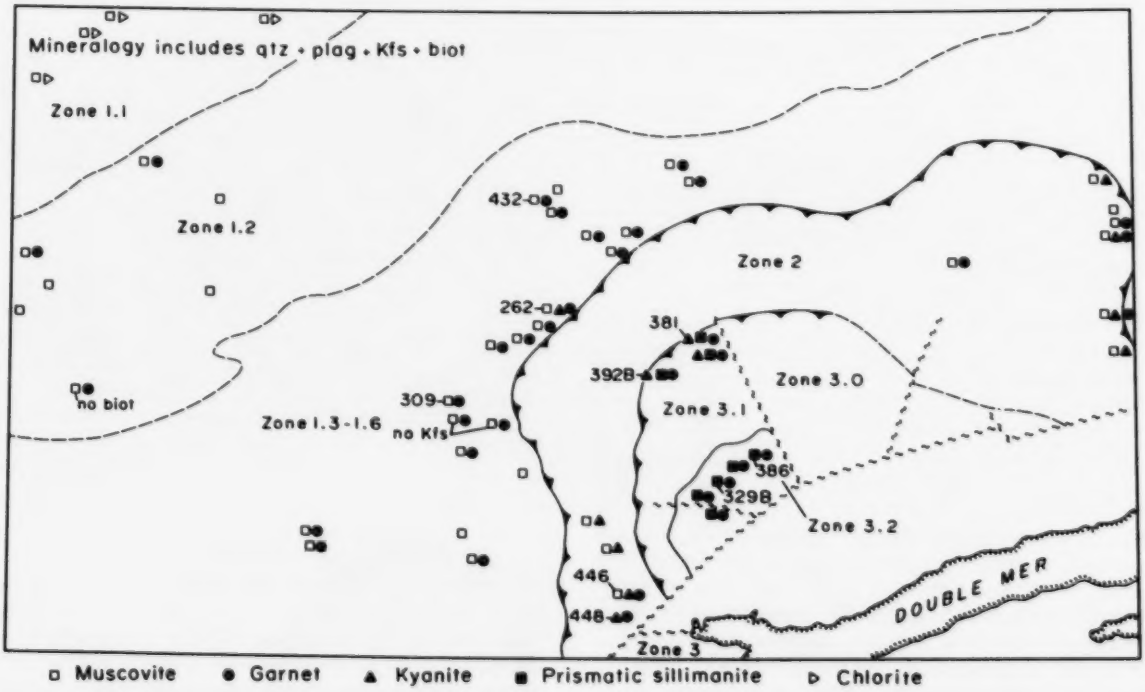

Figure 21. Mineralogical variations in quartz + plagioclase + K-feldspar + biotite + muscovite metasedimentary and granitic rocks.

Table 2. Summary of major mineral associations

Zone 1	
qtz + plag + biot + musc ± kfs ± gnt	Pelitic-granitic gneiss
qtz + plag + biot + kfs + epd ± hbl ± gnt ± scp	Quartzofeldspathic orthogneiss
Zone 2	
qtz + plag + biot + kyn + kfs ± musc ± gnt	Pelitic-granitic gneiss
qtz + plag + biot + kfs ± hbl ± gnt ± ?opx	Quartzofeldspathic orthogneiss
qtz + plag + kfs + hbl + gnt + scp + ?opx	Quartzofeldspathic orthogneiss
qtz + plag + epd + hbl + cpx + sph	Calc-silicate rocks
Zone 3	
qtz + plag + biot + kfs + gnt ± kyn ± sill	Pelitic-granitic gneiss
qtz + plag + kfs + hbl + gnt ± biot ± opx ± cpx ± scp	Quartzofeldspathic orthogneiss
qtz + plag + hbl + cpx + scp ± kfs ± biot ± opx	Calc-silicate rocks
plag + cpx ± kfs ± gnt ± scp	Calc-silicate rocks
qtz + plag + hbl + gnt ± cpx ± scp ± kfs ± biot ± opx	Calc-silicate rocks
biot – biotite	musc – muscovite
cpx – clinopyroxene	opx – orthopyroxene
epd – epidote	plag – plagioclase
gnt – garnet	qtz – quartz
hbl – hornblende	scp – scapolite
kfs – K-feldspar	sill – sillimanite
kyn – kyanite	sph – sphene

Table 3. Variations in major minerals within pelitic and calc-silicate metasedimentary gneiss between metamorphic zones 1, 2 and 3.

Mineral	Zone 1	Zone 2	Zone 3.1	Zone 3.2
Pelitic rock				
K-feldspar	microcline	microcline & perthite	perthite	perthite
biotite	green	green and brown	brown	brown
garnet	red, rare	red, common	mauve, very common	mauve, abundant
musc/Al_2SiO_5	muscovite	muscovite & kyanite	kyanite & sillimanite	sillimanite
accessories	apatite	rare apatite	hercynite, no apatite	hercynite, no apatite
Calc-silicate rock				
amphibole		green hornblende	green-brown hornblende	green-brown hornblende
sphene/garnet		sphene	garnet or sphene	garnet
epidote/scapolite		epidote	scapolite	scapolite
orthopyroxene (pelitic/calc-silicate)			hypersthene	hypersthene

Small grains of granoblastic kyanite (less than 0.2 mm across) occur as trains enclosed in, and partially retrograded to muscovite in one sample of muscovite granite (unit 4u). This single occurrence may simply mean that conditions for generating kyanite were locally achieved in the high grade part of zone 1. Alternatively, the fact that kyanite occurs as relict grains extensively retrograded to muscovite may imply that kyanite was at one time more widespread in zone 1, but in rocks without kyanite, retrogression to muscovite is complete. Although the second, more complex explanation may seem initially less probable it should be noted that the kyanite occurrence is in a homogeneous granitoid rock enveloped in muscovite-bearing gneiss. It was suggested earlier that the gneiss may be a deformed equivalent of the granite; thus the deformation and fluid introduction, which facilitated the formation of gneiss, also could have caused kyanite retrogression to muscovite, except where the pre-existing rock (i.e. unit 4u) remains as tectonic enclaves.

Zone 2 in pelitic rocks is marked by the widespread appearance of kyanite. The boundary between zones 1 and 2 is poorly defined in muscovite/aluminosilicate-bearing assemblages, but is better established in hornblende-bearing quartzofeldspathic gneiss. The boundary is probably a thrust, interpreted and positioned from structural and aeromagnetic data.

Kyanite in zone 2 occurs as either subidiomorphic grains or granoblastic aggregates, in part associated with muscovite. The status of muscovite is equivocal; in some rocks it appears to be stable, in others it is confined to particular layers that may be later shears. In the eastern part of the area some muscovite is undoubtedly retrograde, directly pseudomorphous after kyanite or K-feldspar. In these rocks, coexisting kyanite and K-feldspar indicate that conditions for bathozone 6 (P greater than 720 MPa, T greater than 650°C; *cf.* Carmichael, 1978), have been achieved for at least part of zone 2. However several examples are known in which large muscovite flakes appear stable in contact with both kyanite and K-feldspar. The northern muscovite-kyanite-garnet occurrence in the eastern area, plotted in Figure 21, also has rare fibrolite. This is interpreted as a retrograde product because the needles are randomly oriented across grain boundaries in places.

Perthitic K-feldspar and brown biotite also appear in zone 2, in contrast to microcline and green biotite seen in zone 1, although microcline and green biotite persist in zone 2.

In zone 2 kyanite preferentially coexists with either garnet or muscovite. This is taken to indicate the reaction (Thompson, 1976, 1982; Holdaway, 1980):

Muscovite + Garnet = Kyanite + Biotite + Quartz 1

with either muscovite or garnet surviving, depending on which reactant is exhausted first. The rocks containing kyanite + muscovite + garnet may represent reaction boundary assemblages or mean that muscovite is a retrograde or relict phase.

Zone 3 corresponds with the Lake Melville terrane. Mineral assemblages in metasedimentary gneiss in the Double Mer White Hills domain allow two subzones to be defined. In zone 3.1 kyanite is the dominant aluminosilicate and occurs as bladed grains. Prismatic sillimanite is also present, but is minor. In one sample (in which kyanite is absent) felted fibrolite, inferred to be retrograde, was observed. Muscovite is absent. Garnet is abundant as grains commonly exceeding 0.5 cm diameter, and is mauve rather than red, as in preceding zones. K-feldspar is entirely perthitic, biotite is pale orange-brown and minor hercynite is present.

Zone 3.2 is characterized by prismatic sillimanite + K-feldspar assemblages. Mauve garnet is abundant, K-feldspar is perthitic, biotite is red-brown and hercynite is a common accessory phase. Biotite is less abundant than in preceding zones. No sillimanite + hypersthene assemblages were observed except for a doubtful example in the Double Mer domain. This rock contains bastite that may be pseudomorphous after orthopyroxene, and an acicular mineral, possibly sillimanite. This assemblage has not been plotted on Figure 21.

Amphibole-bearing quartzofeldspathic rocks

The indirect compositional constraint imposed on this group of rocks is that their mineralogy includes quartz + plagioclase + K-feldspar + biotite + amphibole. Amphibole is not necessarily a member of the stable mineral assemblage in all rocks, being relict in parts of zone 1 and possibly retrograde in places in zone 3.

Furthermore, the biotite-present constraint does not apply in the higher grade rocks of zone 3, which contain equivalent, but largely anhydrous assemblages. Garnet-bearing, amphibole-absent assemblages are also indicated on Figure 22. The broad screening adopted includes diverse rock types varying from mafic rocks with minor quartz and K-feldspar to felsic rocks with minor amphibole.

No subdivision of zone 1 is possible using amphibole-bearing assemblages. Except for three samples of Walker Lake quartz monzonite, the Trans-Labrador batholith is excluded by the amphibole-present criterion. Metamorphic effects are seen from textures however. Primary igneous phases have irregular, recrystallized borders and are enveloped in a fine grained, recrystallized matrix. Even where the primary grain shape is present, internal polygonization is evident. Calcic parts of plagioclase are altered to clinozoisite and sodic parts to white mica. K-feldspar shows partial or complete inversion from stringlet perthite to microcline, which has been subsequently partly altered to white mica. All recrystallized K-feldspar is microcline. Amphibole is a blue-green relict mineral, largely pseudomorphed by biotite + epidote (*cf.* Marmo, 1971). Olive-green biotite is locally altered to chlorite ± white mica ± epidote ± K-feldspar ± sphene. Farther south in zone 1 (within the Groswater Bay terrane) rocks have foliated to gneissic, entirely recrystallized fabrics. K-feldspar is invariably microcline and biotite is bronzy green. Garnet is absent from amphibole-bearing quartzofeldspathic rocks in zone 1, although it occurs in similar biotite-bearing (amphibole-absent) gneiss in the southeastern part of the zone. Garnet is also present within the amphibole-bearing, more alkali-rich rocks of unit 5. This unit meets the screening criteria for this group of rocks but overall it is compositionally distinct. Clinozoisite/epidote is characteristic of zone 1. Its abundance decreases southward. Scapolite appears sporadically in more calcic lithologies.

Zone 2 is marked by the appearance of garnet in amphibole-bearing quartzofeldspathic gneiss. Garnet is also widespread in amphibole-absent, but otherwise similar, quartzofeldspathic gneiss. The presence or absence of clinozoisite/epidote allows subdivision of zone 2. The dividing line is very approximate on Figure 22, because of sparse outcrop. In zone 2.2, in which clinozoisite/epidote is absent, three samples were noted to contain a serpentine pseudomorph of a phase interpreted to have been orthopyroxene. In one sample small relict cores of orthopyroxene are still preserved. Scapolite is also a widespread mineral in zone 2; its occurrence is largely controlled by bulk composition. Compositional considerations also account for the lack of biotite in some scapolite-bearing rocks. The decrease in clinozoisite/epidote, appearance of garnet and increasingly widespread development of scapolite are probably the result of several interdependent reactions collectively generating garnet and

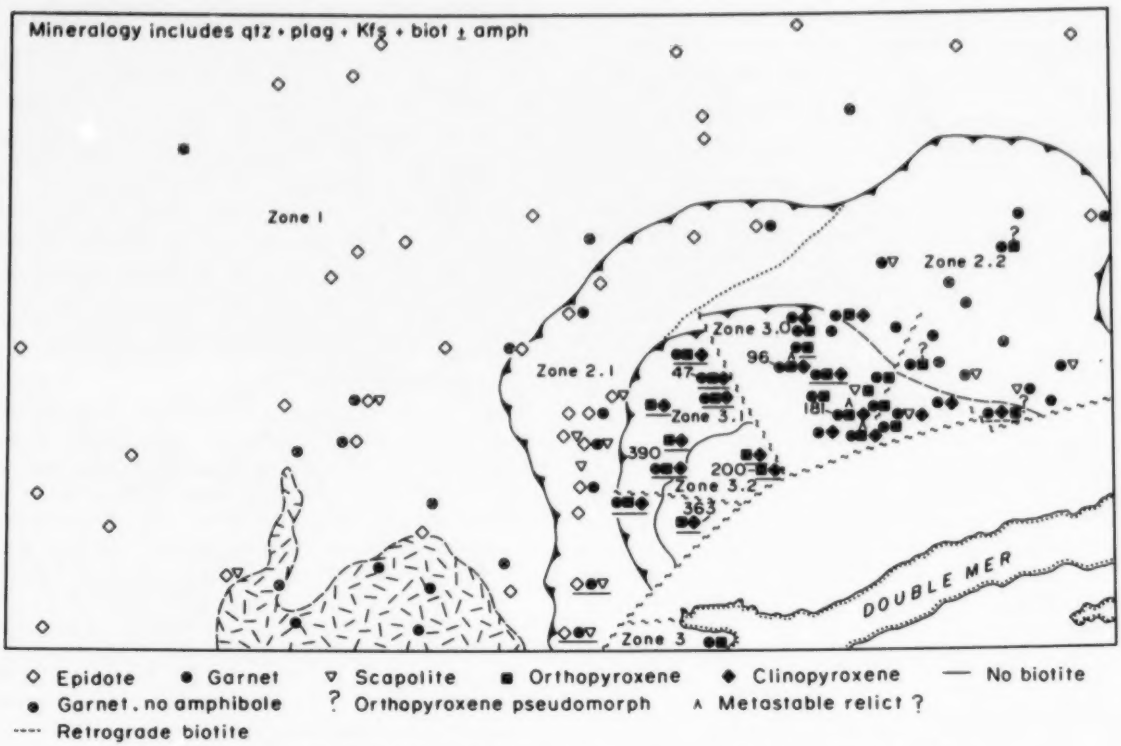

Figure 22. Mineralogical variations in quartz + plagioclase + K-feldspar + biotite + amphibole quartzofeldspathic rocks.

scapolite at the expense of clinozoisite/epidote, and possibly also quartz and plagioclase.

Epidote was noted by Gower (1983) as a mineral characteristic of the Groswater Bay terrane. It has been subsequently interpreted as a retrograde phase by Erdmer (1984) or as a stable mineral of parageneses which also include hornblende, garnet and biotite (Wardle and Ash, 1984). Both viewpoints are probably oversimplifications. Marginal to the Crooked River granite much of the epidote (with biotite) is pseudomorphous after hornblende and is therefore related to retrograde (or later lower grade) metamorphism. Throughout the Mulligan River domain epidote is zoned. The rims are interpreted as retrograde (or due to late lower grade metamorphism) with the interior representing a stable phase of the earlier higher grade paragenesis (or parageneses), which is still represented by most of the mineral assemblage. In the Partridge Point Brook domain overgrowths are absent; this is taken to indicate that the secondary retrograde (later metamorphism) epidote did not form either because the rocks passed through a lower PT regime too fast (retrograde) and/or that activity of water was too low (retrograde or late metamorphism). The appearance of scapolite is the first conclusive evidence that activity of water is less than 1.0. Increasing mol fraction of CO_2 in the fluid also suppresses formation of clinozoisite. Calcareous metasediments found associated with pelitic and semipelitic schists in both zone 2 and zone 3 provide a source for CO_2.

The sporadic existence of (now pseudomorphed) orthopyroxene in quartzofeldspathic gneiss poses a similar problem as kyanite in zone 1. Does the orthopyroxene indicate that granulite facies conditions were locally achieved; or are the pseudomorphs the sole remaining evidence of widespread granulite facies assemblages in zone 2, that extensive retrogression has elsewhere obliterated?

Zone 3 is marked by the more or less simultaneous appearance of orthopyroxene + garnet in felsic granulite and clinopyroxene + garnet in mafic granulite. In the granulites of the Double Mer Barrens domain garnet is abundant and biotite minor, whereas in the Double Mer White Hills domain granulites garnet is sparse and biotite absent. Amphibole in zone 3 is a dark green-brown hornblende typical of hydrous granulite facies rocks.

The appearance of orthopyroxene in felsic granulites may indicate the reaction (de Waard, 1965; Jen and Kretz, 1981):

Hornblende + Biotite + Quartz = Orthopyroxene + K-feldspar + Plagioclase + H_2O 2

Garnet is already a stable phase from lower grade reactions. Additional garnet may be generated, and excess biotite consumed by the reaction (de Waard, 1965):

Biotite + Quartz = Orthopyroxene + K-feldspar + Garnet + H_2O 3

These reactions have the effect of producing rocks of 'monzonitic' composition from hornblende-biotite granodiorite gneiss. Thus unit 1p (K-feldspar augen biotite gneiss) could well be equivalent to unit 6m (monzonite granulite = mangerite).

The lack of orthopyroxene in mafic granulites may indicate the reaction (Carmichael, 1974; Froese and Jen, 1979):

Hornblende + Plagioclase + Quartz = Clinopyroxene + Garnet + H_2O 4

In the Double Mer domain the presence of hornblende + garnet + quartz reaction rims between orthopyroxene and plagioclase indicates the granulite to upper amphibolite retrograde reaction:

Orthopyroxene + Plagioclase + H_2O = Hornblende + Garnet + Quartz 5

Coronitic metagabbroid rocks

Zone 1 can be subdivided into six subzones on the basis of mineralogy and textures in coronitic metagabbroid rocks with separate assemblages being characteristic of zone 2. Some of the subzones in zone 1 are not strictly metamorphic zones in that they are partly identified on textural rather than mineralogical criteria. A summary of the progressive changes in each major primary phase with increasing metamorphism is given in Table 4.

Zone 1.1 is characterized by rocks with almost entirely primary igneous minerals, namely olivine, plagioclase, clinopyroxene, biotite and opaque minerals. Orthopyroxene and amphibole are additional rare primary phases but they are too sporadic to enable progressive changes to be documented, and have been omitted from Table 4. The only 'metamorphic' feature in zone 1 is the presence of extremely narrow coronas of orthopyroxene (less than 0.005 mm wide) marginal to olivine.

Zone 1.2 is characterized by orthopyroxene – clinopyroxene + spinel or orthopyroxene – amphibole + spinel multiple coronas. The mineralogy of similar coronas seen farther north and east was referred to by Gower (1981a) and Gower et al. (1982) as tremolite-actinolite, but electron microprobe analyses (Emslie, 1983; Appendix 1, this paper) have indicated that this is incorrect and that the coronal phases are as noted above and following. The multiple coronas in zone 1.2 between olivine and plagioclase are commonly greater than 0.5 mm wide. Partial amphibole coronas exist between plagioclase and opaque mineral + biotite. Concomitantly orthopyroxene – opaque mineral symplectites replace olivine.

The orthopyroxene – amphibole + spinel corona reaction between olivine and plagioclase has been discussed in detail as a series of partial reactions by Van Lamoen (1979) and Zeck et al. (1982) and combined to give the following gener-

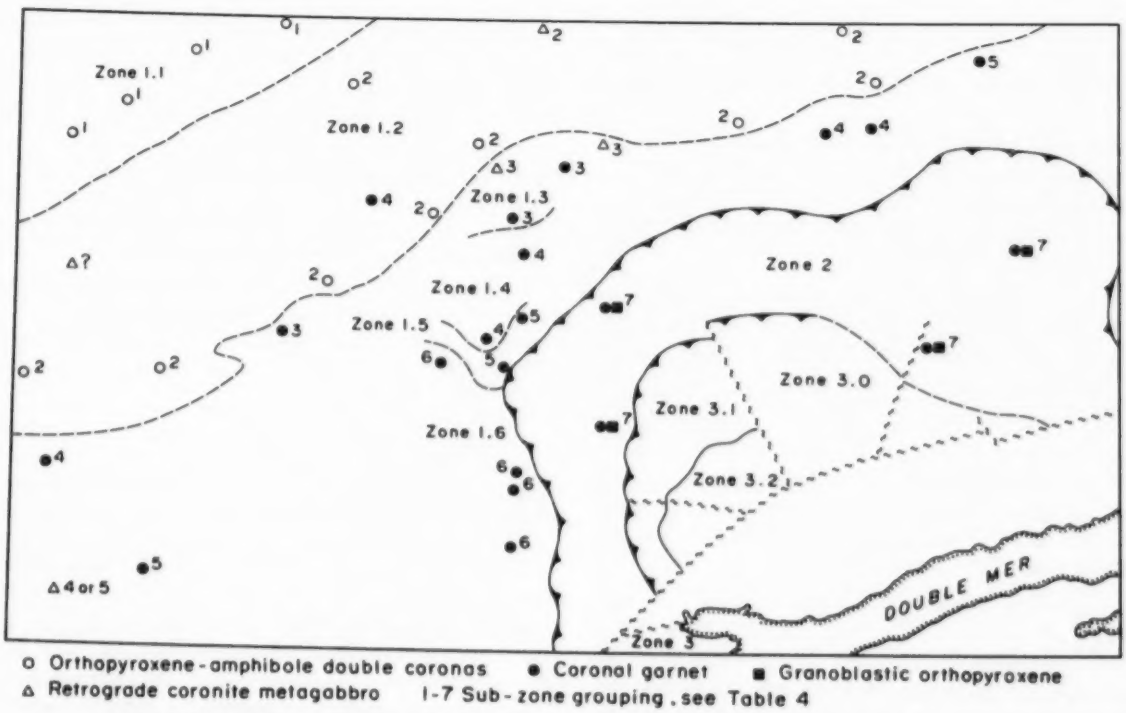

Figure 23. Distribution of coronitic metagabbroid types according to zonal scheme presented in Table 4.

Table 4. Mineralogical and textural variations in coronitic metagabbro.[1]

Zone 1.1	Zone 1.2	Zone 1.3	Zone 1.4
Olivine			
Primary phase, fractured but not extensively altered to Fe-oxides, very narrow coronas.	Primary phase with local alteration along fractures. Multiple opx-cpx/amph + spinel coronas.	Primary phase, pervasively altered with development of opx-opq symplectite. Wide opx-cpx/amph + spinel coronas with local gnt.	Rare primary phase, mostly replaced by opx-opq symplectite. Multiple opx + cpx + amph + spinel + gnt coronas.
Plagioclase			
Primary, well twinned, colourless, straight grain boundaries.	Primary, well twinned, brown colour due to very minute spinel inclusions. Local wavy, recrystallized grain boundaries.	Primary, well twinned, brown with poorly developed clear moats marginal to coronas. Wavy/recrystallized grain boundaries. Spinel inclusions larger.	Primary, well twinned. Brown except where corundum platelets developed. Well developed, clear moats marginal to coronas. Spinel inclusion obvious.
Clinopyroxene			
Primary, brown, no coronas.	Primary, brown, no coronas.	Primary, brown, very thin ? amphibole coronas in places, some exsolved opq.	Primary and locally recrystallized. Amphibole or gnt coronas. Exsolved opq.
Biotite			
Primary, mantling opq grains in part	Primary, mantling opq grains. Amphibole coronas in places.	Primary and recrystallized aggregates. Partial coronas around opq. Gnt associated with recrystallized biotite.	Recrystallized aggregates in coronas around opq grains.
Opaque Mineral			
Primary	Primary with amphibole and/or biotite coronas. Hercynite associated.	Primary with amphibole biotite and garnet coronas common. Hercynite common. Secondary in opx-opq symplectite.	Primary with amphibole, biotite and garnet coronas. Also secondary in opx-opq symplectite.

[1]Abbreviations as in Table 2; amph – amphibole; opq – opaque

alized reaction (Kushiro and Yoder, 1966; Whitney and McLelland, 1973, 1983; Griffin and Heier, 1973; Gardner and Robins, 1974; Davidson, A., personal communication, 1985),

Plagioclase (2Ab+4An) + 12 Olivine + Magnetite + $2H_2O$ = 12 Hypersthene + 2 Ferripargasite + 1 Hercynite 6

Under anhydrous conditions clinopyroxene is a product instead of amphibole + spinel.

Zone 1.3 is characterized by the appearance of garnet as a coronal phase marginal to olivine and also associated with biotite aggregates around opaque minerals. The formation of coronal garnet in olivine metagabbro has been discussed by Griffin and Heier (1973) and more recently by McLelland and Whitney (1980a,b), Whitney and McLelland, (1983) and Johnson and Essene (1982). The garnet-producing reaction can be summarized qualitatively as follows:

Plagioclase + Orthopyroxene + Amphibole + Spinel = Garnet + Clinopyroxene + more Na-rich Plagioclase 7

Clear plagioclase moats which are seen marginal to coronal garnet can be explained by consuming spinel from spinel-clouded plagioclase, to leave clear Na-rich plagioclase.

In zone 1.4 corundum platelets are obvious in plagioclase, and garnet is a common coronal phase around opaque minerals. Bohlen and Essene (1975) suggested the reaction

Plagioclase + Magnetite + Quartz = Garnet + Sodic Plagioclase + O_2 8

to explain the formation of garnet marginal to opaque minerals. The corundum platelets may be due to exsolution at high pressures with the concomitant formation of non-stoichiometric, Al-deficient plagioclase (Goldsmith, 1980), or perhaps the product of Al generated as an excess component from the formation of progressively more sodic plagioclase.

In zone 1.5 primary olivine has been replaced completely by an orthopyroxene-opaque mineral symplectite. Garnet is a coronal phase around extensively recrystallized clinopyroxene, for which the following reaction may apply (for details *see* Griffin and Heier, 1973).

Clinopyroxene + Plagioclase = secondary Clinopyroxene + Garnet 9

A similar reaction can be written in which primary orthopyroxene, plagioclase and quartz are replaced by clinopyroxene and garnet (McLelland and Whitney, 1977). In zone 1.6 primary igneous minerals have been almost entirely recrystallized with only rare relict plagioclase and clinopyroxene remaining.

Zone 2 is characterized by the presence of polygonal (granoblastic) orthopyroxene associated with recrystallized clinopyroxene, garnet and plagioclase. Zone 2 metagabbroid rocks all have granulite facies metamorphic mineral assemblages.

Table 4. (cont'd)

Zone 1.5	Zone 1.6	Zone 2
		Orthopyroxene
No primary olivine. Relict olivine cores replaced by aggregate of opx-opq. Multiple coronas of opx + amph + gnt.	No olivine remaining. Recrystallization so extensive that former location of olivine grains difficult to ascertain.	Granoblastic, pleochroic grains associated with clinopyroxene.
Relict primary, well twinned grains. Shape substantially modified by recrystallization. Remnant brown patches with coarse spinel inclusions. Abundant corundum platelets.	Rare, relict colourless primary grains with corundum platelets. Mostly recrystallized to moderately twinned polygonal aggregates without corundum platelets.	Rare relict primary grains with spinel and corundum inclusions. Mostly recrystallized to polygonal aggregates.
Primary, but extensively recrystallized in places to pale green aggregates. Garnet coronas separated from cpx by clear plagioclase moats.	Rare, relict primary grains. Mostly recrystallized to polygonal aggregates associated with biotite, opq and plagioclase. Plagioclase moats between opx and gnt.	Rare relict primary grains. Mostly recrystallized to polygonal aggregates.
Recrystallized aggregates in coronas around opq grains. Also with recrystallized cpx.	Recrystallized aggregates associated with opq and cpx.	Coarsely recrystallized aggregates mantling opq.
Partially recrystallized with biotite and garnet coronas, especially garnet.	Recrystallized aggregates associated with biotite.	Recrystallized aggregates.

Retrograde mafic rocks are locally associated with coronitic metagabbro. These have developed in schistose zones, marginal to fractures and pegmatites, and at metagabbro-quartzofeldspathic plutonic rock contacts. All retrograde samples examined in thin section occur in zone 1 (Fig. 23). Each instance of retrogression can be related to local avenues of fluid access, but no regional pattern is apparent.

The mineralogy is plagioclase + amphibole + brown biotite + opaque mineral + apatite ± garnet ± epidote ± zircon. The plagioclase appears least affected by the regression and its appearance is used here as a criterion of the subzone to which the metagabbro originally belonged. No coronal textures or other primary phases are necessarily preserved. Amphibole occurs as colourless and green recrystallized aggregates in the cores and rims of mafic clusters respectively. They perhaps represent their retrograded coronal orthopyroxene and amphibole counterparts. Locally, necklaces of garnet attest to the presence of former garnet coronas. Biotite occurs as recrystallized aggregates marginal to opaque grains. It is also dispersed throughout. Epidote is most abundant in rocks with least primary plagioclase remaining and appears to be related to the extent of retrograde metamorphism.

In retrograded mafic rocks garnet also occurs as large (0.5-1.0 cm) subhedral to euhedral individual crystals texturally distinct from the previously described coronal garnet. The field association of this form of garnet with avenues of fluid access is quite evident. These rocks also have less K-feldspar and more biotite, perhaps implying a hydration reaction that presumably also involved an opaque mineral as a reactant, for example (Wones and Eugster, 1965)

$$K\text{-feldspar} + Magnetite + H_2O = Biotite + Quartz \quad 10$$

Calc-silicate metasedimentary gneiss

The restricted distribution of calc-silicate rocks prevents a full assessment of mineral assemblage variations across the zonal scheme outlined. Apart from one occurrence in zone 2, all outcrops found are confined to the Double Mer White Hills domain of zone 3. The following observations are pertinent however. With increasing metamorphic grade, (i) amphibole changes from pale green to olive-green/brown, (ii) sphene and epidote are eliminated, (iii) garnet and scapolite appear, (iv) sphene and garnet appear to be incompatible, and (v) hypersthene occurs in calc-silicate rocks which also contain K-feldspar and biotite.

Ultramafic rocks

Two outcrops of ultramafic rock occur in zone 1 (approximately zone 1.2 to 1.4) and three in zone 2. The ultramafic rocks in zone 1 have essentially primary mineralogies (noted earlier – unit 7u) and textures with poorly developed orthopyroxene and amphibole + spinel coronas and orthopyroxene + opaque mineral symplectite after olivine. The ultramafic rocks in zone 2 have orthopyroxene + amphibole + opaque mineral ± olivine ± clinopyroxene hercynite. The texture is granoblastic and the mineralogy regarded as entirely a high grade metamorphic assemblage.

Quantitative estimates of metamorphic conditions

Two groups of rocks were selected for geothermometry and geobarometry studies, namely, (i) granulite facies orthogneiss, and (ii) pelitic gneiss. In keeping with the reconnaissance nature of the project, an exhaustive investigation was not undertaken, thus results must be regarded as preliminary. Calculations are based on microprobe data given in Appendix 1.

Granulite facies orthogneiss

Six samples of granulite facies orthogneiss were selected, two each from zones 3.0, 3.1 and 3.2. For this study the two-pyroxene geothermometer, as calibrated by Wells (1977), and the garnet-plagioclase-orthopyroxene-quartz geobarometer (Perkins and Newton, 1981; Newton and Perkins, 1982) were used. Several other geothermometers and geobarometers have been suggested for pyroxene garnet-bearing granulites, and could have been applied here. Few have escaped criticism, however, including the two selected (for reviews *see* Bohlen and Essene, 1979; Newton, 1983), but both the Wells geothermometer and the Newton and Perkins geobarometer have been evaluated for a broad selection of granulite facies terranes, thus allowing for some qualitative adjustments to be discussed in the light of acknowledged shortcomings.

Temperatures calculated using the Wells (1977) calibration of the two-pyroxene geothermometer range from 778 to 904°C with good agreement between the two samples from zone 3.0 (809 and 810°C) and fair agreement between the two from zone 3.1 (843 and 877°C), but marked discrepancy between the two from zone 3.2 (778 and 904°C), see Table 5a.

Calculations were performed assuming all Fe as Fe^{2+}, thus yielding temperatures 10-30°C higher than would have been obtained by estimating Fe^{3+} from stoichiometry. Comparisons between various geothermometers carried out elsewhere (e.g. Rollinson, 1981; Bohlen and Essene, 1979) suggest that the Wells calibration yields temperatures that are about 100°C too high. If these considerations are applicable here then peak metamorphic temperatures of 700-800°C might be more realistic.

The garnet-plagioclase-orthopyroxene-quartz geobarometer can only be applied to samples from zones 3.0 and 3.1, as garnet is absent in the orthogneiss granulite of zone 3.2. Activity of anorthite in plagioclase was calculated using the 'Al-avoidance' model (Kerrick and Darken, 1975; Newton et al., 1980). Activity of enstatite in orthopyroxene was calculated using the ideal two-site solid solution model of Wood and Banno (1973). Activities for grossular and pyrope in garnet were determined according to expressions given by Newton (1983).

Calculations were performed at 600 and 800°C model temperatures, yielding pressures of 8.7-9.3 kb for zone 3.0 and 10.3-10.8 kb for zone 3.1 (Table 5b). Newton and Perkins (1982) have intimated that calculated pressures are high, and suggest an empirical reduction of 0.6 kb from values obtained using their equation.

Solving geothermometric and geobarometric values for pressure and temperature simultaneously (done graphically

Table 5a. Mineral data and calculated temperatures for the granulite facies orthogneiss using the two-pyroxene geothermometer.

Metamorphic zone	Sample no.	Orthopyroxene				Clinopyroxene			–lnKd	Temperature (°C)	
		$X_{\frac{Fe}{Mg+Fe}}$	$X_{Mg}^{M_2}$	$X_{Mg}^{M_1}$	A_{En}^{Opx}	$X_{Mg}^{M_2}$	$X_{Mg}^{M_1}$	A_{En}^{Cpx}		Wood and Banno (1973)	Wells (1977)
3.0	CG-83-96	0.424	0.530	0.555	0.296	0.044	0.605	0.027	2.395	796	809
3.0	CG-83-181	0.423	0.542	0.566	0.307	0.046	0.615	0.028	2.391	797	810
3.1	CG-83-47	0.345	0.639	0.628	0.401	0.057	0.643	0.037	2.383	841	843
3.1	CG-83-390	0.357	0.629	0.616	0.387	0.068	0.643	0.044	2.174	859	877
3.2	CG-83-200	0.372	0.599	0.609	0.355	0.038	0.646	0.024	2.722	786	778
3.2	CG-83-363	0.347	0.636	0.626	0.397	0.082	0.626	0.052	2.033	884	904

X = mol fraction, A = activity of component, En = Mg_2SiO_6

Table 5b. Mineral data and calculated pressures for the granulite facies orthogneiss using the garnet-plagioclase-orthopyroxene-quartz geobarometer

Metamorphic zone	Sample no.	Plagioclase			Garnet							Orthopyroxene			ln Kd		Pressure (bars)	
		X An	A An 600°C	A An 800°C	X Mg	X Fe	X Ca	A Ca 600°C	A Ca 800°C	A Mg 600°C	A Mg 800°C	$X_{Mg}^{M_2}$	$X_{Mg}^{M_1}$	A En	600°C	800°C	600°C	800°C
3.0	CG-83-96	0.166	0.240	0.183	0.187	0.572	0.160	0.188	0.179	0.214	0.205	0.530	0.555	0.296	2.110	1.974	8899	10555
3.0	CG-83-181	0.161	0.230	0.176	0.179	0.579	0.162	0.189	0.181	0.205	0.197	0.542	0.566	0.307	2.182	2.037	8681	10340
3.1	CG-83-47	0.298	0.493	0.382	0.322	0.497	0.153	0.207	0.189	0.361	0.348	0.639	0.628	0.401	1.992	1.901	9262	10821
3.1	CG-83-390	0.315	0.528	0.410	0.305	0.507	0.159	0.211	0.193	0.344	0.331	0.629	0.616	0.387	2.102	2.015	8924	10390

Calculated pressures use the calibration of Newton and Perkins (1982).

in Fig. 24) yields temperatures between 796-887°C and pressures between 10.3-11.0 kb. Assuming that temperatures are 100°C too high and, at the same time, reducing pressures, at the applicable temperature, by 0.6 kb (see earlier comments), a revised estimate of P-T conditions for zone 3.0 and zone 3.1 is approximately 700-775°C and 9-10 kb, with zone 3.1 representing slightly higher P-T conditions than zone 3.0.

Pelitic gneiss

Pelitic gneisses were investigated using the garnet-biotite geothermometer and the garnet-plagioclase – Al_2SiO_5 – quartz geobarometer. For the garnet-biotite geothermometer the calibration of Ferry and Spear (1978) was used, as presented by Hodges and Royden (1984; equation R1). Ferry and Spear indicated that their geothermometer is only appropriate to samples in which X_{Ca}^{Gnt} is less than 0.1; X_{Ca+Mn}^{Gnt} is less than 0.3; $X_{Ti+Al_{vi}}^{Biot}$ is less than 0.15. The formulation of Hodges and Royden makes accommodation for Ca and Mn in garnet and adopts a consistent set of garnet solid solution models for use with the garnet-plagioclase-Al_2SiO_5-quartz geobarometer. Previous calibrations making accommodation for Mn and Ca components (Goldman and Albee, 1977; Pigage and Greenwood, 1982) have been criticized by Indares and Martignole (1984) and St-Onge (1984) who preferred the Thompson and Ferry-Spear calibrations respectively. Although the Hodges and Royden formation used here may itself be criticized in the future it is worth noting that, of the six Al_2SiO_5-bearing, equilibrium assemblages for which temperature estimates are given in Table 6a, only one (CG-83-446) is marginally outside the constraints of Ferry and Spear.

Rims and cores of both biotite and garnet were analyzed but no significant zoning was detected for those samples listed in Table 6a and averaged analytical data are used. All Fe is taken as Fe^{2+}, an assumption that is unlikely to seriously affect the results (*see* Bohlen and Essene, 1980). Temperatures were calculated at model pressures of 5 and 10 kb and yielded a temperature range at 5 kb of 653-833°C between zones 2.1 to 3.2. Temperatures calculated for 10 kb are, on average 22°C higher.

Application of the garnet-plagioclase-Al_2SiO_5-quartz geobarometer (Ghent, 1976, 1977) was made using the Newton and Haselton calibration, as presented by Hodges and Royden (1984). Calculations of partial molar volume of grossular in pyrope-grossular and almandine-grossular garnet was made by proportionally averaging values obtained from an enlarged version of Figure 1 of Newton and Haselton (1981). No accommodation has been made for the effects of Mn on grossular mixing. Newton and Haselton (1981) noted that their geobarometer should be applied only to those assemblages in which X_{Mn}^{Gnt} is less than $\frac{1}{3}X_{Mg}^{Gnt}$. Although this constraint does not apply to the formulation used here it is nevertheless noted that only one sample (CG-83-446) would be excluded.

Pressures were calculated for model temperatures of 600 and 800°C using appropriate equations, according to the equilibrium Al_2SiO_5 polymorph present at time of system closure as given by Hodges and Spear (1982) and Hodges and Royden (1984).

Calculated pressures show a decrease in pressure with increasing metamorphic grade (Table 6b). This is an artifact of presenting the data at a given constant model temperature. Simultaneous solution with results of garnet-biotite geothermometry is done graphically in Figure 24 and gives values of 665-695°C, 7.7-8.5 kb for zone 2.1, 775-830°C, 8.6-9.2 kb for zone 3.1 and 655-700°C, 5.4-5.9 kb for zone 3.2.

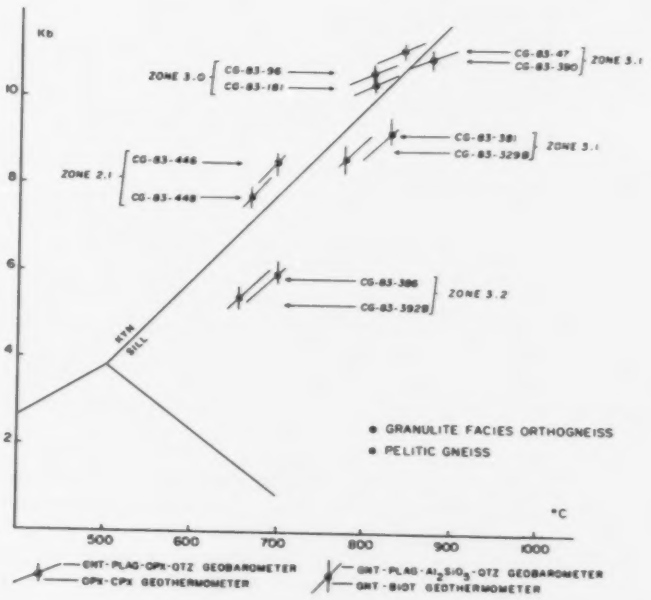

Figure 24. Estimates of P-T conditions for granulite facies orthogneiss and pelitic gneiss from geothermometric and geobarometric calculations. Errors are approximately ± 1.5 kb and ± 50C, according to data given in original publications for geothermometers and geobarometers used.

Table 6a. Mineral data and calculated temperatures for pelitic gneiss using the garnet-biotite geothermometer.

Metamorphic zone	Sample no.	Garnet				Biotite		Ferry and Spear (1978)			Hodges and Royden (1984)		
		X Fe	X Mn	X Mg	X Ca	X Fe	X Mg	-ln Kd	Temperature °C 5 kb	Temperature °C 10 kb	-ln K_1	Temperature °C 5 kb	Temperature °C 10 kb
2.1	CG-83-446	0.489	0.283	0.167	0.061	0.327	0.507	1.516	(657)	(678)	4.361	683	703
2.1	CG-83-448	0.540	0.093	0.310	0.057	0.228	0.633	1.578	632	653	4.549	657	677
3.1	CG-83-329B	0.512	0.018	0.436	0.034	0.217	0.674	1.297	755	778	3.842	764	785
3.1	CG-83-381	0.427	0.015	0.528	0.030	0.170	0.713	1.224	792	816	3.577	809	833
3.2	CG-83-386	0.417	0.032	0.525	0.026	0.141	0.757	1.440	689	710	4.277	695	716
3.2	CG-83-392B	0.510	0.022	0.440	0.028	0.175	0.716	1.553	642	662	4.586	653	672

ln K_1 is a mean value of those used for temperatures calculated.
Temperatures shown in brackets are invalid on Ferry and Spear's criteria.

Table 6b. Mineral data and calculated temperatures for pelitic gneiss using the garnet-plagioclase-Al_2SiO_5-quartz geobarometer (Hodges and Royden, 1984).

Metamorphic zone	Sample no.	Garnet				Plagioclase Xan	ln K_2		ΔV cal-bar^{-1}mol^{-1}	Pressure (bars)	
		XFe	XMn	XMg	XCa		600°C	800°C		600°C	800°C
2.1	CG-83-446	0.489	0.283	0.167	0.061	0.235	4.933	4.294	1.575	6438	10720
2.1	CG-83-448	0.540	0.093	0.310	0.057	0.260	5.028	4.549	1.576	6329	10368
3.1	CG-83-329B	0.512	0.018	0.436	0.034	0.231	5.710	5.360	1.615	5442	9046
3.1	CG-83-381	0.427	0.015	0.528	0.030	0.234	5.825	5.567	1.627	5279	8705
3.2	CG-83-386	0.417	0.032	0.525	0.026	0.257	6.600	6.351	1.357	4246	7682
3.2	CG-83-392B	0.510	0.022	0.440	0.028	0.245	6.490	6.147	1.343	4393	8017

The relative P-T positions for zone 2.1 and zone 3.1 are in agreement with metamorphic assemblages described earlier. The P-T estimate for zone 3.1 is, however, in disagreement with the kyanite-sillimanite phase boundary of Holdaway (1971), suggesting either lower temperatures and/or higher pressures. The P-T field for zone 3.2 appears, at first sight, to be anomalously low, with respect to both pressure and temperature. Certainly the temperature range of 655-700°C from garnet-biotite geothermometry contrasts with the 778-904°C range for the adjacent granulite facies orthogneiss, as indicated from two-pyroxene geothermometry which may mean that the biotite has partially re-equilibrated during uplift. However the lack of garnet in the orthogneiss (which precluded the use of the garnet-plagioclase-orthopyroxene-quartz geobarometer in zone 3.2) may imply lower pressures than in zone 3.1, perhaps meaning that one of the higher pressure, garnet-generating reactions, such as orthopyroxene + plagioclase = clinopyroxene + garnet + quartz, did not take place. If the 778-904°C temperature for zone 3.2 quartzofeldspathic granulite is qualitatively reduced by 100°C as previously discussed, and taken in conjunction with the garnet-plagioclase-Al_2SiO_5-quartz geobarmometer then peak P-T conditions indicated for zone 3.2 are between 700-800°C and 6.0-7.5 kb, still significantly lower with respect to pressure than zone 3.1.

ECONOMIC MINERAL POTENTIAL

A thorough assessment of the economic mineral potential of the area has never been undertaken, due in part to inaccessibility and poor exposure. The region was included in reconnaissance mineral exploration by BRINCO Ltd. (Beavan, 1954, 1955; Morrison, 1957) but results did not warrent follow-up work. As these surveys entailed very rapid coverage of very large areas prior to the availability of geological mapping, geophysical or geochemical data, assessments made, in my opinion, can no longer be regarded as reliable.

More recently, extensive uranium and molybdenum mineralization has been found (BRINEX Ltd) in the upper Aillik Group, in particular the Michelin uranium deposit, located only 8 km north of the present map boundary (*see* Gower et al., 1982 for description and references). Furthermore uranium mineralization has been discovered (Kerswill and McConnell, 1982) and prospected by Northgate Exploration Ltd in the Double Mer area, 9 km south of the map area (Bailey, 1979a, 1980; Erdmer, 1983, 1984; Gower and Erdmer, 1984). Thus, during mapping the intervening region was studied for possible relationships between the two mineralized districts.

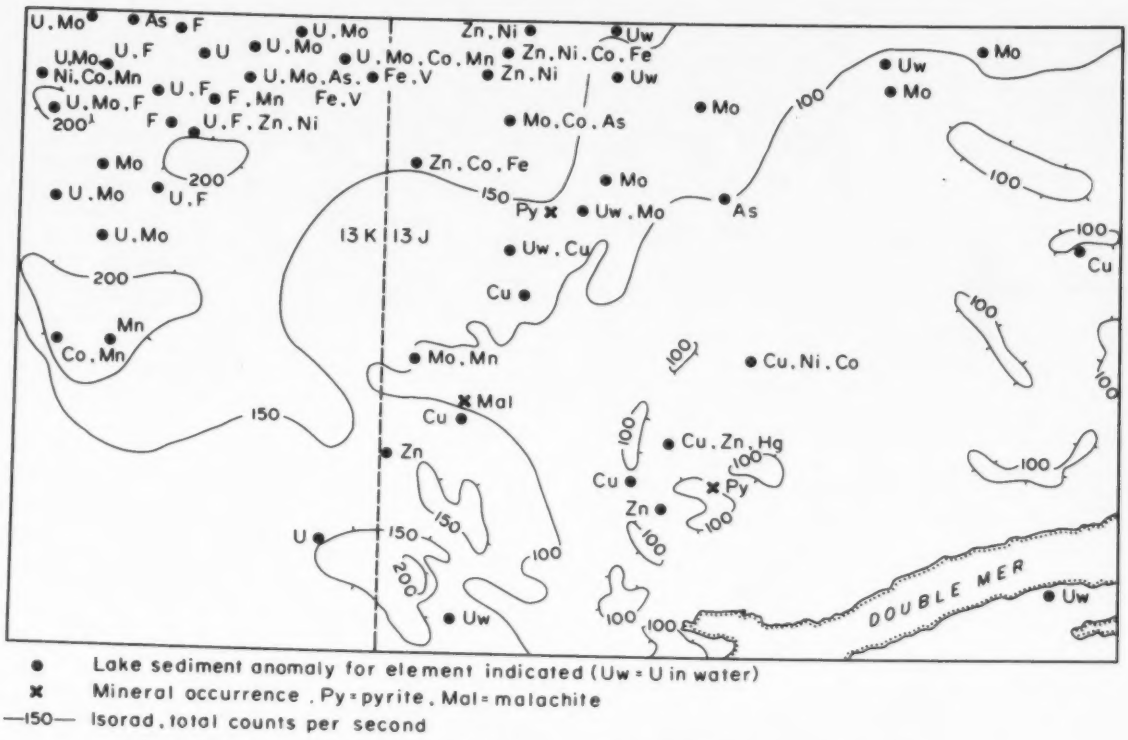

Figure 25. Economic mineral potential map for the Double Mer White Hills region.

Three direct approaches were adopted in assessing mineral potential, namely (i) background radioactivity, (ii) lake sediment geochemical anomalies, and (iii) mineral occurrences. Total count readings were measured using a hand-held scintillometer at every data station. Results (excluding gabbros) have been contoured on Figure 25. The scintillometer survey showed that total counts on bedrock, in all cases attributed to background radiation, decrease from northwest to southeast. The highest values coincide with the Trans-Labrador batholith and the lowest with the granulites of the Lake Melville terrane.

Lake sediment geochemical sampling (Geological Survey of Canada/Newfoundland Department of Mines and Energy 1977, 1984) has been completed for the map region. NTS sheets 13J and 13K were sampled under two separate projects, and hence form two statistically different populations. Thus an anomalous element (at 2σ level) for one NTS sheet may not, in a few cases, be anomalous in the other. Anomalous elements have been plotted on Figure 25, and fall broadly into two groups.

Ni, Co and Fe (locally with Cu and Zn) anomalies are adjacent to mafic intrusions and are unlikely to be of economic interest. Perhaps more important are U and Mo anomalies (locally also with Cu and Zn). These elements delineate a broad arc extending from the northeast corner to the south (centre) map border. The southern part of this arc is underlain by metasedimentary gneiss and muscovite-bearing plutonic rocks. The northern part is unexposed. Bedrock underlying this part of the arc may also include remnants of metasedimentary gneiss but could also be a glacial dispersion pattern from the metasedimentary gneiss farther south. Gower and Erdmer (1984) have drawn attention to a correlation of U, Mo and Cu mineralization with metasedimentary gneiss throughout the Grenville Province in eastern Labrador.

Three mineral occurrences were located during mapping. The northern pyrite occurrence (Fig. 25) and the malachite locality are minor, but it is interesting to note that lake sediment Cu anomalies were detected near both. The host rock in both cases is a rusty weathering biotite-muscovite schist occurring as layers less than 30 cm wide within granitic gneiss. The other mineral occurrence is within the Double Mer White Hills domain of the Lake Melville terrane. It consists of several pyritic layers up to 50 cm thick and locally containing up to an estimated 15% sulphide. The mineralization appears to be stratabound and, although its lateral extent is unknown, the persistence of the horizon in the limited area examined suggests that it may be traceable for some distance. No lakes exist for sampling down-drainage, hence, even if the occurrence contains anomalous metals, they would have escaped detection. A sample analyzed from this locality gave the following results: Au-less than 1 ppb, Ag – less than 1 ppm, Cu – 8 ppm, Zn – 80 ppm, Pb - 8 ppm, Ni – 9 ppm, Mo – 3 ppm.

Mapping in the region has not demonstrated any connection between mineralization in the upper Aillik group and the Double Mer region. The map area and adjacent districts include several major thrust slices which may have considerably telescoped the intervening region, so that any statement made concerning original spatial relationships would be completely speculative.

SUMMARY OF GEOLOGICAL HISTORY

A summary of the proposed geological history of the area is given in Table 7. The earliest stages of the geological history remain obscure. A quartzofeldspathic basement is inferred onto, or adjacent to which the protolith of the metasedimentary gneiss was deposited. No direct evidence of this basement has yet been found in the region. About 2.0 Ga granulite facies gneiss has been reported from the Smokey area (Gower and Owen, 1984a) and similar age (or older) gneiss is known in the Nain Province and adjacent Makkovik Province (Ryan et al., 1983). Both of these areas are within or north of the Trans-Labrador batholith and may not be directly relevant to the Grenville Province. There is no proof that any of the orthogneissic rocks in either the Groswater Bay or Lake Melville terranes are older than associated metasedimentary gneiss.

The inferred oldest recognizable rocks are the pelitic and psammitic gneisses associated with minor quartzite or carbonate (unit 2). The presently favoured hypothesis is that they were deposited under shelf or basin slope conditions marginal to an Archean cratonic nucleus, now represented in part by the Nain Province.

The metasedimentary rocks were then intruded by a wide range of granitoid rocks that include diorite, granodiorite, K-feldspar megacrystic granodiorite, and granite. These rocks include all the granitoid units of units 3, 4 and 5, and much, if not all of unit 1, although still acknowledging that some of unit 1 could include remnants of an earlier quartzofeldspathic basement. The source of these plutonic rocks is unknown. The association of granitic gneiss with remnants of metasedimentary gneiss suggests that some of the granitic gneiss was derived from pre-existing sediment. One would also expect the pre-existing gneissic basement to be extensively remobilized and to be an additional source region for the granitoid rocks. From available geochronological data in adjacent areas, emplacement of these granitoid rocks probably occurred approximately between 1.7 and 1.65 Ga.. The quartz syenite pluton (unit 5) west of Double Mer (ca. 1632 Ma) and also the Walker Lake quartz monzonite (units 4m, 4m/d, 4g; ca. 1628 Ma), Crooked River granite (unit 4f), and rocks tentatively correlated with the Adlavik Intrusive Suite (unit 4r) are interpreted as later manifestations of this plutonism.

The earlier stages of plutonism may have been accompanied by the development of north to northeast structural trends (Makkovikian Orogeny) which, perhaps, in part resulted from reworking of earlier fabrics in the same direc-

Table 7. Summary of geological history

UPPER PROTEROZOIC OR LATER
Normal faulting, reactivating earlier thrusts in part.
Deposition of Double Mer Formation.
GRENVILLIAN OROGENY (ca. 1200-1000 Ma)
Open east-west folds. North-directed thrusting, shallow in south, possibly steeper reverse faults in north. Recumbent folding, formation of south-plunging synform in Double Mer White Hills domain and stretching lineation. Accentuation of gneissosity especially adjacent to, and above thrust surfaces. Faulting (north) and boudinage (centre and south) of gabbro sheets.
Minor granitoid intrusions.
Emplacement of Michael gabbro (ca. 1400 Ma).
Minor mafic dykes.
TRANS-LABRADORIAN MAGMATISM
Minor granitoid intrusions.
Emplacement of Walker Lake quartz monzonite (ca. 1628 Ma).
Crooked River granite, and Adlavik Intrusive Suite.
Emplacement of unit 5y (ca. 1632 Ma).
Emplacement of dioritic, granodioritic, K-feldspar megacrystic granodiorite, granitic plutons and associated minor intrusions.
PRE TRANS-LABRADORIAN MAGMATISM
Probable mafic dyke emplacement.
Deposition of protolith of metasedimentary gneiss.
Quartzofeldspathic basement?

tion. At approximately 1650 Ma, there was a major reorientation of the regional stress field; thus syn-late plutons (including the Trans-Labrador batholith) have a more easterly alignment.

The regional stress field prior to the Grenvillian Orogeny was in part a north-south tensional regime (as indicated by the rift-related supracrustal rocks of the Bruce River and Seal Lake groups, for example). During this period the Michael gabbro (unit 7r) was emplaced at various levels within the crust (ca. 1400 Ma). The shallowest Michael gabbro was probably emplaced at less than 6 km and the deepest levels of emplacement probably exceeded 25 km. There is no evidence to suggest that the gabbros were intruded preferentially to any particular depth in a given area, but subsequent tectonism, bringing up deeper level crust in the south, has created a zonal pattern with shallowly emplaced gabbros preserved in the north and deeply emplaced gabbro exposed in the south. The coronitic fabrics are interpreted as subsolidus cooling isobaric metamorphic reactions which have a variable coronite mineralogy depending on the depth at which cooling was accomplished. Apart from minor granitoid intrusions, there is little evidence of any later magmatism in the region.

The Grenvillian Orogeny, (ca 1.2-1.0 Ga) was mainly a period of uplift. A single K-Ar (biotite) age of 1160 Ma suggests that rocks in the northern Groswater Bay terrane remained above 300°C, or cooled and were reheated above 300°C until that date. Uplift was accomplished by north-directed thrusts and reverse faults. These appear to be shallow dipping structures in the southern part of the region, but were probably steeper reverse faults in the north. The thrusting was accompanied by major recumbent folding, in part responsible for producing the metamorphic contrast between the Groswater Bay and Lake Melville terranes. The prominent stretching lineation seen in Lake Melville terrane rocks (e.g. unit 6) was also formed at this time. Gneissosity in earlier quartzofeldspathic rocks, especially adjacent to, and above, thrust surfaces, was accentuated. The shallow level gabbros (preserved in the north) were mildly disrupted by faulting but their deeper level counterparts were severely boudinaged and locally retrograded (unit 7a) such that formerly continuous sheets are now represented by widely separated pods.

Ongoing erosion presumably culminated during Grenvillian uplift. High grade metamorphic rocks were exposed at the surface prior to, and during the deposition of the terrigenous red beds of the Double Mer Formation. This formation represents the only remaining evidence of that erosion. The age of the Double Mer Formation is unknown but is suspected to be Late Proterozoic or early Paleozoic.

Any younger supracrustal or intrusive rocks have either been eroded or are concealed beneath a thick blanket of glacial surficial deposits which has imparted an east-west drainage and esker pattern to the region.

REFERENCES

Bailey, D.G.

1978: The geology of the Walker Lake – Maclean Lake area (13K/9, 13J/12), Central Mineral Belt, Labrador; *in* Report of Activities for 1977, Newfoundland Department of Mines and Energy, Mineral Development Division, Report 78-1, p. 1-8. .

1979a: Geology of the Double Mer – Lake Melville area, Labrador. Notes to accompany Newfoundland Department of Mines and Energy, Mineral Development Division, Map 79-94.

1979b: Geology of the Walker-Maclean Lake area, 13K/9E, 13J/12, Central Mineral Belt, Labrador, Newfoundland Department of Mines and Energy, Mineral Development Division, Report 78-3, 17 p.

1980: The geology of the Double Mer – Lake Melville area, Labrador; *in* Report of Activities for 1979, Newfoundland Department of Mines and Energy, Mineral Development Division, Report 80-1, p. 154-160.

1981: Kaipokok Bay – Big River, Labrador; Newfoundland Department of Mines and Energy, Mineral Development Division, Map 81-18, scale 1:100 000.

Beavan, A.P.

1954: Report on exploration in Labrador and Newfoundland, 1953; British Newfoundland Corporation Ltd., unpublished report, 76 p.

1955: Report on exploration in Labrador and Newfoundland, 1954; British Newfoundland Corporation Ltd., unpublished report with appendices, 35 p.

Bence, A.E. and **Albee, A.L.**

1968: Empirical correlation factors for the electron microanalysis of silicates and oxides; Journal of Geology, v. 76, p. 382-403.

Bohlen, S.R. and **Essene, E.J.**

1975: Garnet granulites of the Adirondacks; International Conference on geothermometry and geobarometry, Penn. State University, (abstract).

1979: A critical evaluation of two-pyroxene thermometry in Adirondack granulites; Lithos, v. 12, p. 338-345.

1980: Evaluation of coexisting garnet-biotite, garnet-clinopyroxene, and other Mg-Fe exchange thermometers in Adirondack granulites; Geological Society of America, Bulletin, part II, v. 91, p. 685-719.

Bridgwater, D., Watson, J. and **Windley, B.F.**

1973: The Archean craton of the North Atlantic region; Royal Society of London, Philosophical Transactions Series, A. 273, p. 493-512.

Brooks, C.

1983: Fourth report on the geochronology of Labrador; unpublished report to Newfoundland Department of Mines and Energy, Mineral Development Division, 42 p.

Carmichael, D.M.

1974: Mineral equilibria in mafic granulites; Canadian Mineralogist, v. 12, p. 429-430 (abstract).

1978: Metamorphic bathozones and bathograds: a measure of the depth of post-metamorphic uplift and erosion on the regional scale; American Journal of Science, v. 278, p. 769-797.

Christie A.M., Roscoe, S.M., and **Fahrig, W.F.**
1953: Preliminary map, central Labrador coast, Newfoundland (Descriptive Notes); Geological Survey of Canada, Paper 53-14, 3 p.

Clark, A.M.S.
1979: Proterozoic deformation and igneous intrusions in part of the Makkovik Sub-Province, Labrador; Precambrian Research, v. 10, p. 95-114.

de Waard, D.
1965: The occurrence of garnet in the granulite facies terrane of the Adirondack Highlands; Journal of Petrology, v. 6, p. 165-191.

Eade, K.E.
1962: Geology, Battle Harbour – Cartwright, Labrador; Geological Survey of Canada, Map 22-1962.

Emslie, R.F.
1976: Mealy Mountains Complex, Grenville Province, southern Labrador; *in* Report of Activities, Part A, Geological Survey of Canada, Paper 76-1A, p. 165-170.
1983: The coronitic Michael gabbros, Labrador: assessment of Grenvillian metamorphism in northeastern Grenville Province; *in* Current Research, Part A, Geological Survey of Canada, Paper 83-1A, p. 139-145.

Emslie, R.F., Loveridge, W.D., Stevens, R.D. and **Sullivan, R.W.**
1983: Igneous and tectonothermal evolution, Mealy Mountains, Labrador; Geological Association of Canada, Program with Abstracts, v. 8, p. A20 (abstract).

Erdmer, P.
1983: Preliminary report on the geology north of Upper Lake Melville, Labrador; *in* Current Research, Part A, Geological Survey of Canada, Paper 83-1A, p. 291-296.
1984: Geology of the Double Mer – Lake Melville Region, Labrador; Geological Survey of Canada, Paper 84-18, 37 p.

Fahrig, W.R. and **Larochelle, A.**
1972: Paleomagnetism of the Michael Gabbro and possible evidence of the rotation of Makkovik Subprovince; Canadian Journal of Earth Sciences, v. 9, p. 1287-1296.

Ferry, J.M. and **Spear, F.S.**
1978: Experimental calibration of the partitioning of Fe and Mg between biotite and garnet; Contributions to Mineralogy and Petrology, v. 66, p. 113-117.

Froese, E. and **Jen, L.S.**
1979: A reaction grid for biotite-bearing mafic granulites; *in* Current Research, Part A, Geological Survey of Canada, Paper 79-1A, p. 83-85.

Fulton, R.J. and **Hodgson, D.A.**
1979: Wisconsin glacial retreat, southern Labrador; *in* Current Research, Part C, Geological Survey of Canada, Paper 79-1C, p. 17-21.

Gardner, P.M. and **Robins, B.**
1974: The olivine-plagioclase reaction: geological evidence from the Seiland petrographic province, northern Norway. Contributions to Mineralogy and Petrology, v, 44, p. 149-156.

Geological Survey of Canada
1970a: Aeromagnetic Map, Mulligan River, Newfoundland, 13K/1; Geological Survey of Canada, Map 6124G, scale 1:63 360.
1970b: Aeormagnetic Map, 13K/8, Newfoundland; Geological Survey of Canada, Map 6136G, scale 1:63 360.
1971a: Aeromagnetic map, 13J/5, Newfoundland; Geological Survey of Canada, Map 6135G, scale 1:63 360.
1971b: Aeromagnetic Map, 13J/6, Newfoundland; Geological Survey of Canada, Map 6134G, scale 1:63 360.
1971c: Aeromagnetic Map, Double Mer, Newfoundland, 13J/3; Geological Survey of Canada, Map 6124G, scale 1:63 360.
1971d: Aeromagnetic Map, 13J/4, Newfoundland; Geological Survey of Canada, Map 6123G, scale 1:63 360.
1976a: Aeromagnetic Map, Snegamook Lake, 13K; Newfoundland; Geological Survey of Canada, Map 7405G, scale 1:250 000.
1976b: Aeromagnetic Map, Rigolet, 13J, Newfoundland; Geological Survey of Canada, Map 7404G, scale 1:250 000.
1977: National Geochemical Reconnaissance, Map 24-1977; Geological Survey of Canada, Open File 513.
1984: National Geochemical Reconnaissance, Map 62-1983; Geological Survey of Canada, Open File 997.

Ghent, E.D.
1976: Plagioclase-garnet-Al_2Si0_5-quartz: a potential geobarometer-geothermometer; American Mineralogist, v. 61, p. 710-714.
1977: Application of activity-composition relations to displacement of a solid-solid equilibrium. Grossular = anorthite + kyanite + quartz; *in* Short Course in Application of Thermodynamics to Petrology and Ore Deposits, Mineralogical Association of Canada, p. 99-108.

Goldman, D.S. and **Albee, A.L.**
1977: Correlation of Mg/Fe partitioning between garnet and biotite with $^{18}0/^{16}0$ partitioning between quartz and magnetite; American Journal of Science, v. 277, p. 750-767.

Goldsmith, J.R.
1980: The melting and breakdown reactions of anorthosite at high pressures and temperatures; American Mineralogist, v. 65, p. 272-284.

Gower, C.F.
1981a: The geology of the Benedict Mountains, Labrador (13J northeast and 13I northwest); Newfoundland Department of Mines and Energy, Mineral Development Division, Report 81-3, 26 p.
1981b: The geological and geochemical characteristics of the Benedict Mountains Intrusive Suite, Labrador; Geological Association of Canada, Program with Abstracts, v. 6, p. A-22 (abstract).
1983: Lithotectonic and metamorphic subdivision of the Grenville Province in eastern Labrador; *in* Current Research in the Geological Sciences in Canada, May, 1982 – April, 1983. Geological Survey of Canada, Paper 83-5, p. 5
1984: Geology of the Double Mer White Hills and surrounding region, Grenville Province, eastern Labrador; *in* Current Research, Part A, Geological Survey of Canada, Paper 84-1A, p. 553-561.

Gower, C.F. and **Erdmer, P.**
1984: The mineral potential of paragneiss in the Grenville Province in eastern Labrador; *in* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 84-1, p. 80-87.

Gower, C.F., Flanagan, M.J., Kerr, A., and **Bailey, D.G.**
1982: Geology of the Kaipokok Bay – Big River area, Central Mineral Belt, Labrador; Newfoundland Department of Mines and Energy, Mineral Development Division, Report 82-7, 77 p.

Gower, C.F., Gillespie, R.T., Noel, N., Bailey, D.G., and **Doherty, R.A.**
1983a: Rigolet; Newfoundland Department of Mines and Energy, Mineral Development Division, Map 83-42, scale 1:100 000.

Gower, C.F., Noel, N., Gillespie, R.T., Finn, G., and **Emslie, R.F.**
1983b: English River; Newfoundland Department of Mines and Energy, Mineral Development Division, Map 83-44, scale 1:100 000.

Gower, C.F. and **Owen, V.**
1984a: Pre-Grenvillian and Grenvillian lithotectonic regions in eastern Labrador – correlations with the Sveconorwegian Orogenic Belt in Sweden; Canadian Journal of Earth Sciences, v. 21, p. 678-693.
1984b: The Grenville Province in eastern Labrador – correlations with the Sveconorwegian Orogenic Belt in Sweden; Geological Association of Canada, Program with Abstracts, v. 9, p. 68 (abstract).

Gower, C.F. and **Ryan, A.B.**
Proterozoic evolution of the Grenville Province and adjacent Makkovik Province in eastern-central Labrador; *in* The Grenville Province; Geological Association Canada, Special Paper (in press).

Gower, C.F., Ryan, A.B., Bailey, D.G., and **Thomas, A.**
1980: The position of the Grenville Front in eastern and central Labrador; Canadian Journal of Earth Sciences, v. 17, p. 784-788.

Grasty, R.L., Rucklidge, J.C., and **Elders, W.A.**
1969: New K-Ar age determinations on rocks from the east coast of Labrador; Canadian Journal of Earth Sciences, v. 6, p. 340-344.

Greene, B.A.
1972: Geological map of Labrador (1:1 000 000 scale); Mineral Resources Division, Department of Mines, Agriculture and Resources, Province of Newfoundland and Labrador.

Griffin, W.L. and **Heier, K.S.**
1973: Petrological implications of some corona structures; Lithos, v. 6, p. 315-335.

Halet, R.A.
1946: Geological reconnaissance of the Naskaupi Mountains and adjoining coastal region; Private report, Dome Exploration Ltd., 25 p.

Hodges, K.V. and **Royden, L.**
1984: Geologic thermobarometry of retrograded metamorphic rocks: an indication of the uplift trajectory of a portion of the northern Scandinavian Caledonides; Journal of Geophysical Research, v. 89, p. 7077-7090.

Hodges, K.V. and **Spear, F.S.**
1982: Geothermometry, geobarometry and the Al_2SiO_5 triple point at Mt. Moosilauke, New Hampshire; American Mineralogist, v. 67, p. 1118-1134.

Holdaway, M.J.
1971: Stability of andalusite and the aluminum silicate phase diagram; American Journal of Science, v. 271, p. 97-131.
1980: Chemical formulae and activity models for biotite, muscovite, and chlorite applicable to pelitic metamorphic rocks; American Mineralogist, v. 65, p. 711-714.

Indares, A. and **Martignole, J.**
1984: Evolution of P-T conditions during a high-grade metamorphic event in the Maniwaki area (Grenville Province); Canadian Journal of Earth Sciences, v. 21, p. 853-863.

Jen, L.S. and **Kretz, R.**
1981: Mineral chemistry of some mafic granulites from the Adirondack region; Canadian Mineralogist, v. 19, p. 479-491.

Johnson, and **Essene, E.J.**
1982: The formation of garnet in olivine-bearing metagabbros from the Adirondacks. Contributions to Mineralogy and Petrology, v. 81, p. 240-251.

Kerrick, D.M. and **Darken, L.S.**
1975: Statistical thermodynamic models for ideal oxide and silicate solid solutions, with application to plagioclase; Geochimica et Cosmochimica Acta, v. 39, p. 1431-1442.

Kerswill, J.A. and **McConnell, J.W.**
1982: Geochemistry and geology of some uraniferous granites in Labrador; *in* Uranium in Granites, ed. Y.T. Maurice; Geological Survey of Canada, Paper 81-23, p. 171-172.

Kindle, E.M.
1924: Geography and geology of Lake Melville district, Labrador Peninsula. Geological Survey of Canada, Memoir 141, 71 p.

Klassen, R.A.
1984: A preliminary report on drift prospecting studies in Labrador: part II; *in* Current Research, Part A, Geological Survey of Canada, Paper 84-1A, p. 247-254.

Kontak, D.J.
1979: Report on Rb/Sr and U/Pb dating in the Central Mineral Belt of Labrador; Newfoundland Department of Mines and Energy, Mineral Development Division, unpublished Report, 39 p.

Krogh, T.E.
1983: Unpublished report to Newfoundland Department of Mines and Energy, Mineral Development Division.

Kushiro, I. and **Yoder, H.S.**
1966: Anorthite-forsterite and anorthite-enstatite reactions and their bearing on the basalt-eclogite transformation; Journal of Petrology, v. 7, p. 337-362.

Marmo, V.
1971: Granite Petrology and the Granite Problem; Elsevier Publishing Co., Amsterdam, 244 p.

McConnell, J.W.
1979: Geochemical follow-up studies in Labrador; *in* Report of Activities for 1978; Newfoundland Department of Mines and Energy, Mineral Development Division, Report 79-1, p. 159-162.

McLelland, J.M. and **Whitney, P.R.**
1977: The origin of garnet in the anorthosite – charnockite suite of the Adirondacks; Contributions to Mineralogy and Petrology, v. 60, p. 161-181.
1980a: A generalized garnet-forming reaction for metaigneous rocks in the Adirondacks; Contributions to Mineralogy and Petrology, v. 72, p. 111-122.
1980b: Compositional controls on spinel clouding and garnet formation in plagioclase of olivine metagabbros, Adirondack Mountains, New York; Contributions to Mineralogy and Petrology, v. 73, p. 243-251.

Morrison, E.R.
1957: Preliminary report on the geological mapping of the Asbestos Corporation Joint Venture – Kaipokok Concession; Asbestos Corporation – Brinex, unpublished report, 19 p.

Newfoundland Gazette
1980a: Newfoundland Gazette, v. 55, No. 13, p. 333-335.
1980b: Newfoundland Gazette, v. 55, No. 45, p. 1046-1050.

Newton, R.C.
1983: Geobarometry of high-grade metamorphic rocks; American Journal of Science, v. 283-A, p. 1-28.

Newton, R.C., Charlu, T.V., and **Kleppa, O.J.**
1980: Thermochemistry of the high structural state plagioclases; Geochimica et Cosmochimica Acta, v. 44, p. 933-941.

Newton, R.C. and **Haselton, H.T.**
1981: Thermodynamics of the garnet-plagioclase – Al_2SiO_5-quartz geobarometer; *in* Thermodynamics of Minerals and Melts. ed. A. Navrotsky, R.C. Newton, and B.J. Wood. New York, Springer, p. 129-145.

Newton, R.C. and **Perkins III, D.**
1982: Thermodynamic calibration of geobarometers based on the assemblages garnet-plagioclase-orthopyroxene (clinopyroxene)-quartz; American Mineralogist, v. 67, p. 203-222.

Nunn, G.A.G. and **Christopher, A.**
1983: Geology of the Atikonak River area, Grenville Province, western Labrador; *in* Current Research, Part A, Geological Survey of Canada, Paper 83-1A, p. 363-370.

Nunn, G.A.G., Noel, N., and **Culshaw, N.G.**
1984: Geology of the Atikonak Lake area, Grenville Province, western Labrador; *in* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 84-1, p. 30-41.

Owen, V., Rivers, T., and **Gower, C.F.**
The Grenville Front on the Labrador coast; *in* The Grenville Province, Geological Association of Canada, Special Paper (in press).

Perkins III, D. and **Newton, R.C.**
1981: Charnockite geobarometers based on coexisting garnet-pyroxene-plagioclase-quartz; Nature, v. 292, p. 144-146.

Perry, J.
1979: Annual Exploration Report, 1978, Canico-Brinex Joint Venture Areas, Moran and Seal Lake area, Lab.; Canico-Brinex unpublished report, 31 p.

Pigage, L.C. and **Greenwood, H.J.**
1981: Internally consistent estimates of pressure and temperature: the staurolite problem; American Journal of Science, v. 282, p. 943-969.

Rivers, T.
1983: The northern margin of the Grenville Province in western Labrador – anatomy of an ancient orogenic front; Precambrian Research, v. 22, p. 41-73.

Rollinson, H.R.
1981: Garnet-pyroxene thermometry and barometry in the Scourie granulites, NW Scotland; Lithos, v. 14, p. 225-238.

Ryan, A.B.
1981: Volcanism, sedimentation, plutonism and Grenvillian deformation in the Helikian basins of central Labrador; *in* Proterozoic Basins of Canada, ed. F.M.A. Campbell; Geological Survey of Canada, Paper 81-10, p. 361-378.
1982: Geology of the Central Mineral Belt, Labrador; Newfoundland Department of Mines and Energy, Mineral Development Division, Maps 82-3, 82-4.
1985: Regional geology of the central part of the Central Mineral Belt, Labrador; Newfoundland Department of Mines and Energy, Mineral Development Division, Memoir 3, 185 p.

Ryan, A.B. and **Harris, A.**
1978: Geology of the Otter-Nipishish-Stipec Lakes area, Labrador (13K/2,3,6,7); *in* Report of Activities for 1977. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 78-1, p. 51-58.

Ryan, A.B., Kay, A. and **Ermanovics, I.F.**
1983: Notes to accompany Maps 83-8 to 83-41 showing the geology of the Makkovik Subprovince between Kaipokok Bay and Bay of Islands, Labrador; Newfoundland Department of Mines and Energy, Mineral Development Division, 21 p.

Ryan, A.B., Neale, T. and **McGuire, J.**
1982: Descriptive notes to accompany geological maps of the Grand Lake area, Labrador, 13F/10,11,14,15; Newfoundland Department of Mines and Energy, Mineral Development Division, 14 p.

Smyth, W.R.
1977: The geology of the Stipec Lake – Walker Lake area, Central Mineral Belt, Labrador; *in* Report of Activities for 1976. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 77-1, p. 50-56.

Smyth, W.R., Marten, B.E. and **Ryan, A.B.**
1975: Geological mapping in the Central Mineral Belt, Labrador: redefinition of the Croteau Group; *in* Report of Activities for 1974; Newfoundland Department of Mines and Energy, Mineral Development Division, Report 75-1, p. 51-74.

Steiger, R.H. and **Jäger, E.**
1977: Subcommission on geochronology: convention on the use of decay constants in geo- and cosmochronology; Earth and Planetary Science Letters, v. 36, p. 359-362.

Stevenson, I.M.
1969: Rigolet and Groswater Bay map-areas, Newfoundland-Labrador (13I, J); *in* Report of Activities, Part A; Geological Survey of Canada, Paper 69-1. p. 184-185.
1970: Rigolet and Groswater Bay map-areas, Newfoundland (Labrador) (13J, 13I); Geological Survey of Canada, Paper 69-48, 24 p.

St-Onge, M.R.
1984: Geothermometry and geobarometry in pelitic rocks of north-central Wopmay Orogen (early Proterozoic), Northwest Territories, Canada; Geological Society of America, Bulletin, v. 95, p. 196-208.

Thomas, A., Culshaw, N.G., Mannard, G., and **Whalen, G.**
1984: Geology of the Lac Ghyvelde – Lac Long area, Grenville Province, Labrador and Quebec; *in* Current Research, Part A, Geological Survey of Canada, Paper 84-1A, p. 485-493.

Thomas, A., Jackson, V., and **Finn, G.**
1981: Geology of the Red Wine Mountains and surrounding area, central Labrador; *in* Current Research, Newfoundland Department of Mines and Energy, Mineral Development Division, Report 81-1, p. 111-120.

Thomas, A., Nunn, G.A.G., and **Krogh, T.**
Recent geological and geochronological data, north-central margin of the Grenville Province in Labrador; *in* The Grenville Province, Geological Association of Canada, Special Paper (in press).

Thomas, A. and **Wood, D.**
1983: Geology of the Winokapau Lake area, Grenville Province, central Labrador; *in* Current Research, Part A, Geological Survey of Canada, Paper 83-1A, p. 305-312.

Thompson, A.B.
1976: Mineral reactions in pelitic rocks: I Prediction of P-T-X (Fe-Mg) phase relations, II. Calculation of some P-T-X (Fe-Mg) phase relations; American Journal of Science, v. 276, p. 401-454.
1982: Dehydration melting of pelitic rocks and the generation of H_2O-undersaturated granitic liquids; American Journal of Science, v. 282, p. 1567-1595.

van Lamoen, H.
1979: Coronas in olivine gabbro and iron ores from Susimaki and Riuttamaa, Finland; Contributions to Mineralogy and Petrology, v. 68, p. 259-268.

Wagg, D.M.
1968: Airborne Geophysical Survey: Kaipokok Ujutok-Shapio and Recce; British Newfoundland Exploration Ltd., unpublished report, 15 p.

Wanless, R.K., Stevens, R.D., Lachance, G.R., and **Delabio, R.N.**
1972: Age determinations and geological studies; K-Ar Isotopic ages. Report 10; Geological Survey of Canada, Paper 71-2, 96 p.

Wardle, R.J.
1982: Geology of the Churchill Falls region; *in* Current Research, Newfoundland Department of Mines and Energy, Mineral Development Division, Report 82-1, p. 131-148.

Wardle, R.J. and **Ash, C.**
1984: Geology of the North West River area; *in* Current Research, Newfoundland Department of Mines and Energy, Mineral Development Division, Report 84-1, p. 53-67.

Wardle, R.J. and **Britton, J.M.**
1981: The geology of the Churchill Falls area, Labrador; *in* Current Research, Newfoundland Department of Mines and Energy, Mineral Development Division, Report 81-1, p. 130-137.

Wardle, R.J., Rivers, T., Gower, C.F., Nunn, G.A.G., and **Thomas, A.**
A new look at the Grenville Province of Labrador – eastern Quebec; *in* The Grenville Province, Geological Association of Canada, Special Paper (in press).

Wardle, R.J. and **staff, Labrador Section**
1982: The Trans-Labrador batholith; a major pre-Grenvillian feature of the eastern Grenville Province; *in* Grenville Workshop, 1982, Program with Abstracts, Ottawa-Carleton Centre for Geoscience Studies, p. 11.

Wells, P.R.A.
1977: Pyroxene thermometry in simple and complex systems; Contributions to Mineralogy and Petrology, v. 62, p. 129-139.

Whitney, P.R. and **McLelland, J.M.**
1973: Origin of coronas in metagabbros of the Adirondack Mts., N.Y.; Contributions to Mineralogy and Petrology, v. 39, p. 81-98.
1983: Origin of biotite-hornblende-garnet coronas between oxides and plagioclase in olivine metagabbros, Adirondack Region, New York; Contributions to Mineralogy and Petrology, v. 82, p. 34-41.

Williams, F.M.G.
1967: Snegamook (13K, E 1/2) map-area; *in* Report of Activities, Part A, Geological Survey of Canada, Paper 67-1, p. 195-196.
1970: Snegamook Lake (east half), Newfoundland; Geological Survey of Canada, Open File 42.

Wones, D.R. and **Eugster, H.P.**
1965: Stability of biotite: experiment, theory and application; American Mineralogist, v. 50, p. 1224-1272.

Wood, B.J. and **Banno, S.**
1973: Garnet-orthopyroxene and orthopyroxene-clinopyroxene relationships in simple and complex systems; Contributions to Mineralogy and Petrology, v. 42, p. 109-124.

Young, G.M.
1981: Upper Proterozoic supracrustal rocks of North America: a brief review; Precambrian Research, v. 15, p. 305-330.

Zeck, H.P., Shenouda, H.H., Ronsbo, J.G., and **Poorter, R.P.E.**
1982: Hypersthene-ilmenite(/magnetite) symplectites in coronitic olivine-gabbronorites; Lithos, v. 15, p. 173-182.

APPENDIX 1 MINERAL ANALYSES

CG-83-47 Leucomonzonite granulite (6l), zone 3.1

	Gnt	Plag	KFs	Cpx	Opx	Opq
SiO_2	39.96	62.82	66.10	53.04	52.59	0.02
TiO_2	nd	nd	nd	0.16	nd	14.51
Al_2O_3	21.06	23.82	17.89	3.77	2.28	0.12
FeOt	23.71	0.01	nd	8.84	21.61	70.99
MnO	1.30	nd	0.01	0.17	0.55	0.05
MgO	8.61	0.01	nd	12.88	23.03	0.24
CaO	5.71	5.80	0.04	21.25	0.22	nd
Na_2O	0.08	7.51	1.20	1.16	0.04	0.09
K_2O	nd	0.07	13.56	nd	nd	nd
Total	100.43	100.04	98.80	101.27	100.32	86.02
n	3	3	3	3	3	1
cations per x oxygens						
x	12	8	8	6	6	
Si	3.051	2.772	3.044	1.946	1.943	
Al	1.897	1.239	0.972	0.163	0.099	
Ti	–	–	–	0.004	–	
Fe	1.515	–	–	0.271	0.668	
Mn	0.084	–	–	0.005	0.017	
Mg	0.980	0.001	–	0.704	1.269	
Ca	0.467	0.274	0.002	0.835	0.009	
Na	0.012	0.643	0.107	0.082	0.003	
K	–	0.004	0.797	–	–	
Mg/Mg + Fe	0.393			0.722	0.655	
Ab		69.8	11.8			
An		29.8	0.2			
Or		0.4	88.0			

n number of analyses
nd not detected

CG-83-181 Monzonite granulite (6m), zone 3

	Gnt	Plag	KFs	Cpx	Opx	Opq
SiO_2	38.95	65.63	64.39	52.65	51.93	nd
TiO_2	0.02	nd	0.26	0.09	0.07	46.84
Al_2O_3	19.94	21.65	17.90	2.36	1.47	0.04
FeOt	27.22	0.05	0.03	10.98	25.95	55.13
MnO	3.74	nd	nd	0.40	1.34	0.68
MgO	4.73	nd	nd	11.84	19.82	1.09
CaO	5.95	3.54	0.02	20.57	0.48	nd
Na_2O	0.02	10.23	1.80	1.30	0.01	0.09
K_2O	nd	0.32	13.86	nd	nd	0.03
Total	100.57	101.42	98.26	100.19	101.07	103.90
n	3	3	3	3	2	1
cations per x oxygens						
x	12	8	8	6	6	
Si	3.064	2.860	3.006	1.974	1.954	
Al	1.849	1.114	0.986	0.105	0.066	
Ti	0.001	–	0.009	0.003	0.002	
Fe	1.791	0.002	0.001	0.344	0.817	
Mn	0.249	–	–	0.013	0.043	
Mg	0.555	–	–	0.661	1.111	
Ca	0.501	0.166	0.001	0.826	0.019	
Na	0.003	0.865	0.163	0.094	0.001	
K	–	0.018	0.825	–	–	
Mg/Mg + Fe	0.237			0.658	0.577	
Ab		82.5	16.5			
An		15.8	0.1			
Or		1.7	83.4			

CG-83-96 Monzonite granulite (6m), zone 3

	Gnt	Plag	KFs	Cpx	Opx	Opq
SiO_2	39.53	65.53	64.46	52.63	52.39	0.04
TiO_2	0.01	nd	0.20	0.13	nd	12.70
Al_2O_3	20.32	21.76	17.57	2.38	1.07	0.16
FeOt	26.95	0.04	0.05	11.28	25.21	79.80
MnO	3.76	nd	nd	0.46	1.65	0.05
MgO	4.94	nd	nd	11.87	19.21	0.03
CaO	5.91	3.66	0.01	20.29	0.55	0.02
Na_2O	0.02	10.13	1.40	1.46	0.08	nd
K_2O	nd	0.28	14.90	nd	nd	0.02
Total	101.44	101.40	98.59	100.50	100.16	92.82
n	3	3	3	3	6	1
cations per x oxygens						
x	12	8	8	6	6	
Si	3.071	2.857	3.014	1.970	1.984	
Al	1.861	1.119	0.969	0.105	0.048	
Ti	0.001	–	0.007	0.004	–	
Fe	1.752	0.001	0.002	0.353	0.798	
Mn	0.247	–	–	0.015	0.053	
Mg	0.572	–	–	0.662	1.084	
Ca	0.492	0.171	–	0.814	0.022	
Na	0.003	0.857	0.128	0.106	0.006	
K	–	0.016	0.888	–	–	
Mg/Mg + Fe	0.246			0.652	0.576	
Ab		82.1	12.5			
An		16.4	–			
Or		1.5	87.5			

CG-83-200 Leucomonzonite granulite (6l), zone 3.2

	Plag	KFs	Cpx	Opx	Opq
SiO_2	60.48	65.29	52.64	52.48	0.04
TiO_2	nd	0.11	0.28	0.02	50.86
Al_2O_3	24.21	17.79	3.60	2.16	0.09
FeOt	0.09	0.03	8.97	23.30	48.87
MnO	nd	nd	0.33	0.82	0.39
MgO	nd	nd	12.45	22.07	0.78
CaO	6.85	0.12	21.56	0.45	0.03
Na_2O	8.04	1.16	1.19	0.05	0.13
K_2O	0.21	15.02	nd	0.01	0.02
Total	99.88	99.52	101.02	101.36	101.21
n	3	3	2	3	1
cations per x oxygens					
x	8	8	6	6	
Si	2.701	3.019	1.944	1.939	
Al	1.275	0.970	0.157	0.094	
Ti	–	0.004	0.008	0.001	
Fe	0.003	0.001	0.277	0.720	
Mn	–	–	0.010	0.026	
Mg	–	–	0.685	1.215	
Ca	0.328	0.006	0.853	0.018	
Na	0.696	0.104	0.085	0.004	
K	0.012	0.886	–	–	
Mg/Mg + Fe			0.713	0.628	
Ab	67.2	10.4			
An	31.6	0.6			
Or	1.2	89.0			

CG-83-237 Coronitic Metagabbro ($7r_2$), zone 1.2

	Plag	Ol	Hyp *Inner* corona	Amph *Outer* corona	Cpx	Biot	Opq
SiO_2	53.98	36.75	55.08	39.47	50.81	39.18	0.04
TiO_2	0.03	nd	0.01	0.02	1.29	4.07	54.51
Al_2O_3	27.73	0.07	0.82	18.79	2.93	13.86	0.05
FeOt	0.30	33.04	18.45	9.74	10.18	10.77	45.52
MnO	nd	0.41	0.43	0.09	0.24	0.04	0.50
MgO	0.03	31.07	26.43	13.39	15.80	18.01	1.59
CaO	11.02	0.01	0.25	10.45	17.18	nd	nd
Na_2O	5.47	0.02	nd	2.86	0.55	0.33	0.08
K_2O	0.05	nd	0.01	1.60	nd	9.86	0.01
Total	98.61	101.37	101.48	96.41	98.98	96.12	102.30
n	3	3	2	3	3	3	1
cations per x oxygens							
x	8	4	6	23	6	22	
Si	2.475	0.994	1.978	5.845	1.906	5.690	
Al	1.499	0.002	0.035	3.279	0.129	2.373	
Ti	0.001	–	–	0.002	0.036	0.445	
Fe	0.013	0.747	0.554	1.206	0.319	1.308	
Mn	–	0.009	0.013	0.011	0.008	0.005	
Mg	0.002	1.252	1.415	2.954	0.883	3.898	
Ca	0.542	–	0.010	1.658	0.691	–	
Na	0.486	0.001	–	0.821	0.040	0.093	
K	0.003	–	–	0.302	–	1.827	
Mg/Mg + Fe		0.626	0.718		0.735	0.749	
Ab	52.5						
An	47.2						
Or	0.3						

CG-83-240 Retrograded coronitic metagabbro ($7r_3$), zone 1.3

	Opx aggre.	Amphi aggre.	Grt	Biot	Plag	Opq
SiO_2	55.17	42.74	39.09	36.68	54.33	0.09
TiO_2	0.02	0.06	nd	2.30	0.10	49.64
Al_2O_3	0.64	14.19	20.64	15.44	28.28	0.02
FeOt	21.74	16.53	29.33	16.71	0.09	48.05
MnO	0.57	0.16	2.28	0.03	0.04	0.82
MgO	19.39	10.44	4.13	14.36	nd	0.06
CaO	0.32	10.07	4.90	nd	11.37	nd
Na_2O	0.05	2.32	0.03	0.48	5.29	0.04
K_2O	nd	0.38	nd	8.88	0.03	0.01
Total	97.90	96.89	100.40	94.88	99.53	98.73
n	3	3	3	3	1	1
cations per x oxygens						
x	6	23	12	22	8	
Si	2.076	6.405	3.074	5.540	2.466	
Al	0.028	2.508	1.914	2.749	1.513	
Ti	0.001	0.007	–	0.261	0.003	
Fe	0.684	2.072	1.930	2.111	0.003	
Mn	0.018	0.020	0.152	0.004	0.001	
Mg	1.087	2.332	0.484	3.233	–	
Ca	0.013	1.617	0.412	–	0.553	
Na	0.004	0.674	0.004	0.141	0.466	
K	–	0.073	–	1.711	0.002	
Mg/Mg + Fe	0.614		0.200			
Ab					45.6	
An					54.2	
Or					0.2	

CG-83-246 Coronitic metagabbro ($7r_3$), zone 1.3

	Plag	Ol	Hyp corona	Grt Inner corona	Grt Outer corona	Opq_1	Opq_2
SiO_2	53.54	37.77	54.96	39.62	40.37	0.04	nd
TiO_2	0.05	nd	nd	nd	0.03	51.34	nd
Al_2O_3	28.37	nd	0.40	21.23	21.42	0.05	nd
FeOt	0.34	28.87	17.03	22.66	17.48	48.24	77.84
MnO	0.03	0.17	0.17	0.76	0.27	0.14	0.02
MgO	0.14	33.95	26.65	9.39	6.36	0.93	nd
CaO	10.81	nd	0.23	5.66	13.82	nd	nd
Na_2O	5.12	nd	nd	nd	nd	nd	0.01
K_2O	0.11	nd	nd	nd	nd	0.01	nd
Total	98.51	100.76	99.44	99.32	99.75	100.75	77.87
n	3	3	3	3	3	1	1
cations per x oxygens							
x	8	4	6	12	12		
Si	2.455	1.004	1.999	3.039	3.070		
Al	1.534	–	0.017	1.920	1.921		
Ti	0.002	–	–	–	0.001		
Fe	0.013	0.642	0.518	1.454	1.112		
Mn	–	0.004	0.005	0.049	0.017		
Mg	0.009	1.346	1.445	1.074	0.721		
Ca	0.531	–	0.009	0.465	1.126		
Na	0.455	–	–	–	–		
K	0.007	–	–	–	–		
Mg/Mg + Fe		0.677	0.736	0.425	0.393		
Ab	45.9						
An	53.5						
Or	00.6						

CG-83-262 Kyanite muscovite granite (4u), zone 1.5

	Biot	GntC	GntR	GntA	Plag (Relict)	Plag (Recryst)	KFs	Musc	Kyn
SiO_2	37.75	39.20	38.96	39.17	66.56	67.30	67.00	45.67	38.01
TiO_2	1.61	nd	nd	nd	nd	nd	0.02	0.45	nd
Al_2O_3	17.20	20.63	20.14	20.44	20.95	20.79	17.72	30.97	57.17
FeOt	17.25	26.78	25.74	25.77	0.04	nd	0.03	3.52	0.82
MnO	0.27	8.63	11.22	9.71	nd	0.02	nd	0.03	0.04
MgO	12.52	4.30	3.19	3.80	nd	nd	nd	0.98	0.02
CaO	nd	1.52	1.59	1.54	2.79	2.64	nd	nd	0.02
Na_2O	0.11	0.02	0.03	0.05	9.95	10.16	1.02	0.24	nd
K_2O	9.43	0.01	0.01	0.01	0.18	0.12	14.94	9.73	0.01
Total	96.14	101.09	100.88	100.49	100.47	101.03	100.73	91.59	96.09
n	3	1	1	3	2	3	3	2	1
cations per x oxygens									
x	22	12	12	12	8	8	8	22	
Si	5.620	3.082	3.094	3.098	2.911	2.924	3.047	6.373	
Al	3.019	1.912	1.887	1.908	1.080	1.065	0.950	5.095	
Ti	0.180	–	–	–	–	–	0.001	0.047	
Fe	2.148	1.761	1.710	1.706	0.001	–	0.001	0.411	
Mn	0.034	0.574	0.755	0.651	–	0.001	–	0.004	
Mg	2.778	0.504	0.378	0.448	–	–	–	0.204	
Ca	–	0.128	0.135	0.130	0.131	0.123	–	–	
Na	0.032	0.003	0.004	0.008	0.844	0.856	0.090	0.065	
K	1.791	–	–	–	0.010	0.007	0.887	1.732	
Mg/Mg + Fe	0.564	0.223	0.181	0.208					
Ab					85.7	86.8	9.6		
An					13.3	12.5	–		
Or					1.0	0.7	90.4		

CG-83-309 Muscovite schist (2u), zone 1.6

	Biot	Gnt	Plag	Musc	Opq
SiO_2	38.49	39.18	66.58	47.22	0.07
TiO_2	1.69	nd	nd	0.50	8.68
Al_2O_3	17.52	20.63	21.04	30.46	0.09
FeOt	16.12	21.59	0.04	4.45	79.70
MnO	0.38	13.05	0.01	0.03	0.11
MgO	12.48	3.89	0.01	1.28	nd
CaO	nd	1.57	2.89	nd	nd
Na_2O	0.09	0.04	9.64	0.33	0.02
K_2O	9.04	nd	0.09	9.37	nd
Total	95.81	99.95	100.30	93.64	88.67
n	3	3	3	3	1
cations per x oxygens					
x	22	12	8	22	
Si	5.692	3.104	2.912	6.452	
Al	3.055	1.927	1.085	4.907	
Ti	0.188	–	–	0.051	
Fe	1.994	1.430	0.001	0.509	
Mn	0.048	0.876	–	0.003	
Mg	2.751	0.459	0.001	0.261	
Ca	–	0.133	0.136	–	
Na	0.026	0.006	0.818	0.087	
K	1.706	–	0.005	1.634	
Mg/Mg + Fe	0.580	0.243			
Ab			85.3		
An			14.2		
Or			0.5		

CG-83-363 Leucomonzonite granulite (6i), zone 3.1

	Plag	KFs	Cpx	Opx	Opq
SiO_2	60.97	65.06	52.69	52.81	0.05
TiO_2	nd	0.07	0.32	nd	14.98
Al_2O_3	24.38	17.99	4.11	2.20	0.30
FeOt	0.06	0.04	8.98	21.80	75.62
MnO	nd	nd	0.23	0.65	0.14
MgO	nd	nd	12.84	22.96	0.01
CaO	6.98	0.10	20.26	0.18	0.05
Na_2O	7.99	1.13	1.12	0.01	0.08
K_2O	0.17	15.04	nd	nd	0.01
Total	100.55	99.43	100.55	100.61	91.24
n	3	3	3	3	1
cations per x oxygens					
x	8	8	6	6	
Si	2.703	3.011	1.942	1.947	
Al	1.276	0.982	0.179	0.096	
Ti	–	0.002	0.009	–	
Fe	0.002	0.001	0.277	0.672	
Mn	–	–	0.007	0.020	
Mg	–	–	0.705	1.262	
Ca	0.332	0.005	0.800	0.007	
Na	0.687	0.101	0.080	0.001	
K	0.009	0.888	–	–	
Mg/Mg + Fe			0.718		
Ab	66.8	10.2			
An	32.3	0.5			
Or	0.9	89.3			

CG-83-329B Kyanite-sillimanite gneiss (2k), zone 3.1

	Biot	Gnt	Plag	KFs	Kyn	Opq
SiO_2	38.72	39.83	63.34	65.86	37.89	0.11
TiO_2	3.35	nd	nd	nd	0.01	11.71
Al_2O_3	15.45	21.36	22.05	17.25	58.66	0.18
FeOt	10.45	24.77	0.03	nd	1.49	78.02
MnO	nd	0.86	0.01	0.01	nd	0.05
MgO	18.25	11.85	nd	0.02	nd	0.18
CaO	0.04	1.29	4.56	0.04	nd	nd
Na_2O	0.05	0.05	8.38	1.68	nd	0.01
K_2O	8.66	nd	0.11	13.36	nd	0.02
Total	94.97	100.01	98.48	98.22	98.05	90.28
n	3	3	3	3	1	1
cations per x oxygens						
x	22	12	8	8		
Si	5.628	3.026	2.834	3.055		
Al	2.648	1.913	1.163	0.944		
Ti	0.366	–	–	–		
Fe	1.270	1.574	–	–		
Mn	–	0.056	–	–		
Mg	3.954	1.341	–	0.001		
Ca	0.006	0.105	0.219	0.002		
Na	0.014	0.007	0.727	0.151		
K	1.606	–	0.006	0.791		
Mg/Mg + Fe	0.757	0.460				
Ab			76.4	16.0		
An			23.0	0.2		
Or			0.6	83.8		

CG-83-381 Kyanite gneiss (2k), zone 3.1

	Biot	Gnt	Plag	KFs	Opq	Kyn
SiO_2	38.73	40.69	63.52	65.73	0.04	37.12
TiO_2	3.32	nd	nd	nd	13.90	nd
Al_2O_3	15.67	22.04	22.39	17.71	0.19	57.63
FeOt	8.20	20.94	0.04	0.03	73.18	1.82
MnO	0.03	0.72	0.03	nd	0.10	0.02
MgO	19.25	14.51	nd	nd	0.29	nd
CaO	0.05	1.13	4.55	0.08	nd	nd
Na_2O	0.09	0.04	8.23	2.11	0.01	nd
K_2O	8.41	nd	0.05	12.51	nd	nd
Total	93.75	100.07	98.81	98.17	87.71	96.59
n	5	3	3	3	1	1
cations per x oxygens						
x	22	12	8	8		
Si	5.633	3.026	2.829	3.041		
Ai	2.688	1.933	1.176	0.966		
Ti	0.363	–	–	–		
Fe	0.998	1.302	0.001	0.001		
Mn	0.004	0.046	0.001	–		
Mg	4.173	1.608	–	–		
Ca	0.008	0.090	0.217	0.004		
Na	0.025	0.006	0.711	0.189		
K	1.561	–	0.003	0.739		
Mg/Mg + Fe	0.808	0.553				
Ab			76.4	20.3		
An			23.3	0.4		
Or			0.3	79.3		

CG-83-386 Sillimanite gneiss (2s), zone 3.2

	Biot	Gnt	Plag	KFs	Opq	Sill
SiO_2	39.68	40.74	61.56	65.15	0.07	37.07
TiO_2	2.36	nd	nd	nd	9.09	nd
Al_2O_3	15.43	21.93	22.38	17.27	0.29	56.26
FeOt	6.90	20.31	0.03	0.02	77.87	1.77
MnO	nd	1.52	nd	nd	0.02	0.03
MgO	20.72	14.36	nd	nd	0.16	0.02
CaO	nd	0.99	5.00	0.04	nd	nd
Na_2O	0.09	0.01	7.99	1.50	nd	0.04
K_2O	8.82	nd	0.05	13.35	nd	nd
Total	94.00	99.86	97.01	97.33	87.50	95.19
n	3	3	3	3	1	1
cations per x oxygens						
x	22	12	8	8		
Si	5.722	3.036	2.800	3.050		
Al	2.623	1.928	1.200	0.953		
Ti	0.256	–	–	–		
Fe	0.832	1.266	0.001	0.001		
Mn	–	0.096	–	–		
Mg	4.453	1.595	–	–		
Ca	–	0.079	0.244	0.002		
Na	0.025	0.001	0.705	0.136		
K	1.623	–	0.003	0.798		
Mg/Mg + Fe	0.843	0.558				
Ab			74.1	14.6		
An			25.6	0.2		
Or			0.3	85.2		

CG-83-392B Sillimanite gneiss (2s), zone 3.2

	Biot	Gnt	Plag	KFs	Opq
SiO_2	40.15	40.64	62.30	64.79	0.17
TiO_2	2.39	nd	nd	nd	13.03
Al_2O_3	15.62	21.41	22.83	18.11	0.04
FeOt	8.60	23.73	0.03	0.03	72.88
MnO	0.02	1.00	0.01	0.02	0.01
MgO	19.71	11.46	nd	0.01	0.12
CaO	nd	1.02	4.72	0.08	nd
Na_2O	0.09	0.05	8.02	1.63	0.05
K_2O	8.68	nd	0.07	13.24	0.01
Total	95.26	99.31	97.98	97.91	86.31
n	3	3	3	2	1
cations per x oxygens					
x	22	12	8	8	
Si	5.746	3.086	2.802	3.017	
Al	2.635	1.917	1.210	0.995	
Ti	0.257	–	–	–	
Fe	1.029	1.507	0.001	0.001	
Mn	0.002	0.064	–	0.001	
Mg	4.204	1.297	–	–	
Ca	–	0.083	0.228	0.004	
Na	0.025	0.007	0.699	0.147	
K	1.582	–	0.004	0.787	
Mg/Mg + Fe	0.803	0.463			
Ab			75.2	15.7	
An			24.4	0.4	
Or			0.4	83.9	

CG-83-390 Leucomonzonite granulite (6l), zone 3.2.

	Gnt	Plag	KFs	Cpx	Opx	Opq
SiO_2	40.59	61.60	65.79	53.15	51.89	0.09
TiO_2	0.02	nd	nd	0.22	nd	13.45
Al_2O_3	20.46	24.06	17.60	3.89	2.33	0.18
FeOt	24.02	0.07	nd	8.93	22.13	76.75
MnO	1.38	0.02	0.01	0.20	0.49	0.02
MgO	8.11	nd	0.02	13.10	22.34	0.21
CaO	5.90	6.30	0.05	21.25	0.18	nd
Na_2O	0.02	7.57	1.13	1.02	nd	nd
K_2O	0.01	0.08	13.65	nd	nd	nd
Total	100.51	99.70	98.25	101.76	99.36	90.70
n	3	3	3	3	3	1
cations per x oxygens						
x	12	8	8	6	6	
Si	3.101	2.738	3.049	1.939	1.942	
Al	1.843	1.261	0.962	0.168	0.103	
Ti	–	–	–	0.006	–	
Fe	1.535	0.003	–	0.273	0.693	
Mn	0.089	0.001	–	0.006	0.016	
Mg	0.924	–	0.001	0.712	1.246	
Ca	0.483	0.300	0.003	0.831	0.007	
Na	0.003	0.653	0.102	0.072	–	
K	–	0.004	0.807	–	–	
Mg/Mg + Fe	0.376			0.723	0.643	
Ab		68.2	11.1			
An		31.3	0.3			
Or		0.5	88.6			

CG-83-410 Ultramafite (7u), zone 2.1

	Ol	Opx	Amphi	Opq
SiO_2	41.94	56.20	46.20	0.04
TiO_2	nd	nd	0.63	0.02
Al_2O_3	0.02	3.16	11.45	0.56
FeOt	9.44	7.93	5.29	88.47
MnO	0.25	0.36	0.09	0.30
MgO	51.67	34.62	19.06	1.27
CaO	nd	0.18	12.19	nd
Na_2O	0.02	0.06	1.41	0.06
K_2O	nd	nd	0.12	nd
NiO	0.22	0.05	0.06	0.47
Total	103.56	102.56	96.50	91.19
n	2	2	2	1
cations per x oxygens				
x	4	6	23	
Si	0.991	1.907	6.599	
Al	–	0.126	1.929	
Ti	–	–	0.068	
Fe	0.187	0.225	0.632	
Mn	0.005	0.010	0.011	
Mg	1.822	1.751	4.058	
Ca	–	0.007	1.866	
Na	–	0.004	0.391	
K	–	–	0.022	
Ni	0.004	0.001	0.004	
Mg/Mg + Fe	0.907	0.886	0.866	

CG-83-432 Muscovite schist (2u), zone 1.3

	Biot	GntR	GntC	GntA	Plag	KFs	Musc	Opq
SiO_2	40.38	38.66	39.00	38.63	66.19	65.89	47.59	0.09
TiO_2	1.50	nd	0.13	0.05	nd	nd	1.36	6.09
Al_2O_3	14.79	19.48	19.85	19.52	22.04	17.39	26.76	0.04
FeOt	9.65	5.84	6.10	6.18	0.03	0.01	5.72	89.07
MnO	1.11	27.30	24.70	25.77	nd	0.03	0.08	0.22
MgO	18.25	1.51	3.02	2.45	0.01	nd	2.25	0.02
CaO	nd	5.06	6.55	5.83	3.91	nd	nd	0.02
Na_2O	0.10	0.04	0.06	0.04	9.18	0.59	0.16	nd
K_2O	9.94	0.01	nd	nd	0.17	15.38	9.89	0.03
Total	95.72	97.90	99.41	98.47	101.53	99.29	93.81	95.56
n	3	1	1	3	3	3	3	1

cations per x oxygens

x	22	12	12	12	8	8	22
Si	5.851	3.146	3.102	3.116	2.869	3.049	6.575
Al	2.527	1.868	1.862	1.856	1.126	0.948	4.360
Ti	0.163	–	0.008	0.003	–	–	0.141
Fe	1.170	0.396	0.405	0.417	0.001	–	0.661
Mn	0.136	1.882	1.664	1.760	–	0.001	0.009
Mg	3.942	0.181	0.358	0.295	0.001	–	0.463
Ca	–	0.441	0.558	0.504	0.182	–	–
Na	0.028	0.006	0.009	0.006	0.772	0.053	0.043
K	1.838	0.001	–	–	0.009	0.908	1.744
Mg/Mg + Fe	0.771	0.314	0.469	0.413			
Ab					80.2	5.5	
An					18.8	–	
Or					1.0	94.5	

CG-83-437 Coronitic metagabbro ($7r_1$), zone 1.1

	Ol	Opx	Cpx	Plag	Opq	Biot
SiO_2	35.94	51.73	50.82	54.53	0.05	38.14
TiO_2	0.02	0.04	0.86	nd	55.13	4.34
Al_2O_3	nd	2.31	2.76	27.87	0.02	14.28
FeOt	37.91	21.36	12.88	0.22	45.05	15.78
MnO	0.60	0.43	0.32	0.01	0.60	0.05
MgO	26.18	22.23	15.12	0.02	1.09	14.10
CaO	0.02	0.89	16.42	11.55	0.01	nd
Na_2O	nd	nd	0.38	5.12	nd	0.11
K_2O	nd	nd	nd	0.17	0.01	9.73
Total	100.67	98.99	99.56	99.49	101.96	96.53
n	3	2	3	3	1	3

cations per x oxygens

x	4	6	6	8	22
Si	1.004	1.941	1.914	2.479	5.645
Al	–	0.102	0.123	1.494	2.492
Ti	–	0.001	0.024	–	0.483
Fe	0.886	0.670	0.406	0.008	1.954
Mn	0.014	0.014	0.010	–	0.006
Mg	1.090	1.243	0.849	0.001	3.111
Ca	0.001	0.036	0.663	0.562	–
Na	–	–	0.028	0.451	0.032
K	–	–	–	0.010	1.838
Mg/Mg + Fe	0.552	0.650	0.676		
Ab				44.1	
An				54.9	
Or				1.0	

CG-83-446 Kyanite schist/gneiss (2k), zone 2.1

	Biot	Gnt	Plag	KFs	Musc	Opq	Kyn
SiO_2	38.34	39.02	63.46	65.81	42.95	0.06	37.16
TiO_2	1.84	nd	nd	0.01	0.59	10.00	nd
Al_2O_3	18.19	20.28	22.33	17.64	29.16	0.09	57.86
FeOt	15.12	21.88	0.05	0.02	3.52	82.28	1.83
MnO	0.28	12.50	nd	nd	nd	0.14	0.03
MgO	13.17	4.18	nd	0.01	1.11	nd	0.02
CaO	nd	2.13	5.03	0.01	nd	nd	nd
Na_2O	0.11	0.01	9.05	1.27	0.34	0.07	nd
K_2O	9.84	nd	0.14	14.09	9.92	0.01	nd
Total	96.89	100.00	100.06	98.86	87.59	92.65	96.90
n	3	3	3	4	2	1	1

cations per x oxygens

x	22	12	8	8	22
Si	5.605	3.095	2.809	3.042	6.315
Al	3.135	1.896	1.166	0.961	5.056
Ti	0.202	–	–	–	0.065
Fe	1.848	1.451	0.002	0.001	0.433
Mn	0.035	0.840	–	–	–
Mg	2.869	0.494	–	0.001	0.243
Ca	–	0.181	0.239	–	–
Na	0.031	–	0.777	0.114	0.097
K	1.836	–	0.008	0.831	1.861
Mg/Mg + Fe	0.609	0.254			
Ab			75.9	12.1	
An			23.3	–	
Or			0.8	87.9	

CG-83-448 Kyanite schist/gneiss (2k), zone 2.1

	Biot	Gnt	Plag	KFs	Opq
SiO_2	39.61	40.16	64.21	66.63	0.05
TiO_2	1.96	nd	0.01	nd	9.63
Al_2O_3	17.24	21.41	22.96	18.12	0.14
FeOt	11.04	24.70	0.04	0.03	78.63
MnO	0.06	4.19	nd	nd	0.03
MgO	17.20	7.95	nd	nd	0.05
CaO	nd	2.04	5.12	0.02	nd
Na_2O	0.09	0.05	8.09	1.90	0.06
K_2O	8.95	nd	0.10	13.21	nd
Total	96.15	100.50	100.53	99.91	88.59
n	3	3	3	3	1

cations per x oxygens

x	22	12	8	8
Si	5.681	3.080	2.815	3.035
Al	2.916	1.936	1.187	0.973
Ti	0.211	–	–	–
Fe	1.325	1.585	0.001	0.001
Mn	0.007	0.272	–	–
Mg	3.677	0.909	–	–
Ca	–	0.167	0.241	0.001
Na	0.025	0.008	0.688	0.168
K	1.638	–	0.005	0.768
Mg/Mg + Fe	0.735	0.364		
Ab			73.6	17.9
An			25.8	0.1
Or			0.6	82.0

CG-83-496 Quartz syenite/granite (5y), zone 1.6

	Biot	Gnt	Cpx
SiO_2	36.36	39.11	51.04
TiO_2	4.11	0.01	0.07
Al_2O_3	12.51	19.27	1.62
FeOt	29.41	27.75	20.98
MnO	0.38	4.76	1.23
MgO	4.55	0.91	5.47
CaO	0.02	8.16	19.22
Na_2O	0.11	0.08	1.16
K_2O	8.70	nd	nd
Total	96.15	100.05	100.79
n	2	3	2
cations per x oxygens			
x	22	12	6
Si	5.779	3.135	1.996
Al	2.345	1.821	0.074
Ti	0.491	–	0.002
Fe	3.910	1.860	0.686
Mn	0.051	0.323	0.041
Mg	1.078	0.108	0.319
Ca	0.003	0.701	0.805
Na	0.034	0.012	0.088
K	1.764	–	–
Mg/Mg + Fe	0.216	0.055	0.317

APPENDIX 2 MICROPROBE ANALYTICAL PROCEDURE

Mineral analyses were obtained using the JEOL JXA-50A wavelength dispersive electron microprobe operating at Memorial University of Newfoundland. The system includes three gas flow detectors and a KRISEL control automated system. Operating conditions were as follows: beam current – 22×10^{-9} amp, accelerating voltage – 15 kv, beam diameter – 1 to 3×10^{-6} m, counting time per analysis – 30 seconds or a maximum of 60,000 counts. Matrix effect corrections were made using the method of Bence and Albee (1968). Analyses were performed using a variety of calibrations based on appropriate standards. An indication of analytical errors associated with analysis can be obtained from the data presented in Table 8. Mineral analyses were obtained by C. Gower under the guidence of H. Longerich of the Department of Earth Sciences.

Table 8. Precision and accuracy of mineral analyses as indicated by repeated analyses of standard F-CPX.

	SiO_2	TiO_2	Al_2O_3	FeOt	MnO	MgO	CaO	Na_2O
F-CPX (std)	50.73	0.74	7.86	6.77	0.13	16.65	15.82	1.27
F-CPX $\bar{x}$	50.58	0.73	7.87	6.34	0.11	16.57	15.76	1.32
1σ	0.88	0.09	0.20	0.23	0.03	0.22	0.30	0.09

$\bar{x}$ is mean of 13 analyses

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